

**REPORT
OF
THE PETRO-CHEMICAL
COMMITTEE**



**MINISTRY OF COMMERCE AND INDUSTRY
GOVERNMENT OF INDIA
NEW DELHI**

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CONTENTS

CHAPTER I

INTRODUCTION AND SCOPE OF THE COMMITTEE'S WORK

	PAGE
(i) Introduction	1
(ii) Context of the present enquiry	1
(iii) Appointment of the Committee	2
(a) Terms of Reference	2
(b) Composition	3
(iv) Brief account of the Committee's work	3
(v) Report—Method of Presentation	4

CHAPTER II

A BRIEF REVIEW OF THE DEVELOPMENT OF PETRO-CHEMICAL INDUSTRY IN ADVANCED COUNTRIES

(i) U.S.A.	5
(ii) Organisation of European Economic Cooperation Area	7
(iii) West Germany	8
(iv) United Kingdom	10
(v) Japan	13
(vi) France	15
(vii) Italy	18
(viii) General	20

CHAPTER III

AVAILABILITY OF RAW MATERIAL FEED STOCKS

(i) Ethyl Alcohol	22
(ii) Benzene, Toluene, Xylene and Naphthalene	22
(iii) Calcium Carbide	23
(iv) Natural gas	23
(v) Refinery gases	26
(vi) Naphtha	28
(vii) Aromatic Hydro-carbons	31
(a) Straight-run-Aromatics	31
(b) Aromatics in reformates	33
(c) By-product Benzene	34
(d) Naphthalene	34
(e) Petroleum coke	34
(viii) Wax	35
(ix) Feed-stocks for Carbon Blacks	35
(x) Statements regarding	
(a) Refinery production	37
(b) Estimated consumption of petroleum products during the Third Plan; and	38
(c) Estimated surplus or deficit in the main petroleum products in 1966.	40

(ii)

CHAPTER IV

ORGANIC CHEMICALS AND OTHER PRODUCTS TO BE MANUFACTURED
FROM PETROLEUM PRODUCTS

	PAGE
(i) Introduction	41
(ii) What petro-chemicals and other products to manufacture and in what quantity ?	43
(iii) Tentative targets	43
(iv) Estimated requirements of primary raw materials	45
(v) Estimated requirements by 1965-66 and 1970-71 for	45
(a) Nitrogenous fertilizers	46
(b) Methyl Alcohol	47
(c) Ethyl Alcohol	48
(d) Aromatic Hydro-carbons (benzene, toluene, xylenes and naphthalene)	51
(e) Ethylene and propylene	55
(f) Synthetic Rubber	56
(g) Butane/butylenes	60
(h) Synthetic Detergents	61
(i) Carbon Black	62

CHAPTER V

FACILITIES NEEDED FOR THE MANUFACTURE OF ORGANIC
CHEMICALS AND OTHER PRODUCTS AND RELATED MATTERS

(i) Uses of surplus naphtha	64
(ii) Nitrogenous Fertilizers	65
(iii) Steam-crackers and Refinery in South India	66
(iv) Size of Cracker	67
(v) Location of Crackers	68
(vi) Production of aromatics from petroleum feed-stocks	70
(vii) Utilization of Assam gas	73
(viii) Price of naphtha	74
(ix) Demand and supply of naphtha	75

CHAPTER VI

ESTIMATED CURRENT AVAILABILITY OF ORGANIC CHEMICALS AND
RELATED PRODUCTS, THE EXTENT TO WHICH THE DEMAND FOR
THESE PRODUCTS WOULD HAVE TO BE BASED ON PETROLEUM
AND NON-PETROLEUM FEED-STOCKS, ESTIMATES REGARDING
INVESTMENT, VALUE OF PRODUCTION, ETC.

(i) Current availability of the more Important organic chemicals and other related/derived products and the value of estimated demand for these products by 1965-66 and 1970-71	77
(ii) Extent to which the demand for feed-stocks and derived products would be met from petroleum and non-petroleum sources by the end of Third and Fourth Plans	77
(iii) Investment on plant and equipment, and the foreign exchange component of the investment	78
(iv) Tables relating to (i), (ii) and (iii)	80

(iii)

CHAPTER VII

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

LIST OF APPENDICES	PAGE
I. Ministry of Commerce and Industry Office Memorandum No. CH (I)-2/(81)/60, dated 10-10-60 regarding composition and terms of reference of the Petro-chemical Committee	96
II. Ministry of Commerce and Industry Office Memorandum No. CH(I)-2 (81)/60 dated 2-11-60 in partial modification of their Office Memorandum of even number, dated 10-10-60	97
III. Information required regarding the availability of petroleum raw materials for Chemical Industry in India	98
IV. List of persons who gave evidence before the Committee	99
V. Data furnished by the Oil Companies:	
(a) Assam Oil Co. Ltd., Digboi	100
(b) Standard Vacuum Refining Co. of India Ltd., Bombay	102
(c) Burmah Shell Refineries Ltd., Bombay	106
(d) Caltex Oil Refining (India) Ltd., Visakhapatnam	109
(e) Indian Refineries Ltd., New Delhi	112
(f) Production from Barauni Refinery	116
VI. Estimated requirements of the more important organic chemicals and related products by 1965-66 and 1970-71 and the extent to which they are covered by licences under the Industries (Development & Regulation) Act	117



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REPORT OF THE PETRO-CHEMICAL COMMITTEE

CHAPTER I

INTRODUCTION AND SCOPE OF THE COMMITTEE'S WORK

Introduction

The three main sources of starting raw materials for the manufacture of synthetic organic chemicals in the world today are : by-products of coal carbonisation and coal-tar distillation, alcohol and carbide, petroleum and natural gas and their derivatives. In India's Second Five-Year Plan it was assumed that the synthetic organic chemical industry in the country would be based, by and large, on alcohol derived from molasses. Other sources of supply of primary Aliphatic raw materials were not visualised with the exception of ethylene from coke-oven gases at Rourkela. The setting up of the coke-ovens and the arrangements for the recovery and processing of the by-products of coal carbonisation, e.g., benzene, toluene, xylene, phenol, naphthalene etc., undertaken in the Second Five-Year Plan made it possible to provide the primary aromatic chemicals for developing the production of organics. By the end of the Second Plan the prospects of a wider raw material base for the organic chemical industry appeared promising as a result of the petroleum naphtha surplus which had become available with the development of petroleum-refining industry in the country. Discovery of natural gas in Assam provided yet another raw material for developing the production of petro-chemicals. There are also prospects of natural gas becoming available in Gujarat. All those factors bearing on new sources of supply of raw materials for the organic chemical industries called for an early re-appraisal of the programmes and the levels of development on the short as well as the long term basis.

Context of the Present Enquiry

2. There is currently an obvious difference between the industrially advanced countries and India; while in the former the Organic Chemical Industry is well-developed, in the latter this industry is in its infancy. There is yet another important difference. In the case of industrially advanced countries the Petro-chemical Industry came on the scene at a time when the coal-tar based Organic Chemical Industry had firmly established itself and yet the Petro-chemical Industry was able to make significant progress in a relatively short period of time. In India, all the three traditional raw materials of Organic Chemical Industry would become available more or less at the same time. As against the current production of 20 million gallons of ethylalcohol, production is expected to go up to nearly 60 million gallons by 1965-66 and almost this entire quantity would be available for the Chemical Industry as the present practice of using alcohol as power alcohol in admixture with gasoline is expected to be discontinued very soon. The availability of benzene from coal-tar for the Organic Chemical Industry would increase

from the present level of about 5,000 tons to about 50,000 tons by 1965-66 when the demand is estimated to be about 80,000 tons which might rise to 170,000 tons by 1970, on the basis of projections made in this report. This would necessitate the production of petrochemical benzene on a large scale. Starting materials from petroleum source are about to become available in substantial quantities. Thus, the Chemical Industry in the country is on the threshold of major developments uninhibited by raw material scarcities and we may confidently expect a prolific growth during the next decade. It is in this context, following a suggestion made at a meeting of the Chairmen of the Development Councils, that this Committee was set up by the Ministry of Commerce and Industry in consultation with the Ministry of Steel, Mines & Fuel and the Planning Commission.

Appointment of the Committee

3. A committee for the preparation of a plan for the development of petro-chemical industries during the Third and the Fourth Five-Year Plans was appointed in terms of Office Memorandum No. CH(1)-2(81)/60, dated the 10th October 1960 (Appendix I) issued by the Government of India in the Ministry of Commerce & Industry. The Terms of Reference of the Committee as well as its composition were amended by a further Office Memorandum No. CH(1)-2(81)/60, dated the 2nd November, 1960 (Appendix II) issued by the Ministry of Commerce & Industry. The background to the appointment of the Committee is stated as follows:

"During the last few years in many advanced countries of the world, products such as synthetic rubber, plastics, insecticides, detergents and organic solvents have been made increasingly as petro-chemicals. In view of the rapidly rising demands of such products in the country and the likely availability of suitable petroleum fractions for their production in the next few years, Government recognise the need to encourage the development of petro-chemical industries. It has, therefore, been decided to set up a Committee to study the subjects in all its aspects so as to evolve a plan for organising such industries during the Third and the Fourth Five-Year Plans".

Terms of Reference

(A) The Terms of Reference of the Committee were as follows :—

- (a) An assessment of the types and quantities of materials whose production may have to be organised in petrochemical industries;
- (b) To evolve a suitable pattern for development in India in the context of the integrated pattern of production of petrochemicals in advanced countries;
- (c) To assess the extent to which the aromatic as well as aliphatic raw materials may have to be produced as petrochemicals during the period 1961 to 1971;
- (d) To recommend the pattern of development of petrochemical industries in the country.

Composition

(B) The Committee consisted of the following :—

- (1) Dr. G. P. Kane, Senior Industrial .. Chairman
Adviser (Chemicals), Development
Wing, Ministry of Commerce and
Industry.
- (2) Shri K. K. Sahni, Joint Secretary, .. Member
Ministry of Steel, Mines & Fuel.
- (3) Dr. J. S. Ahluwalia, Chemical .. Member
Engineer, Ministry of Steel, Mines
& Fuel (now O.S.D., Indian
Institute of Petroleum).
- (4) Shri K. Vyasulu, Chief (Industry), .. Member
planning Commission.
- (5) Dr. A. Seetharamiah, Develop- .. Member-Secretary
ment Officer (Leather & Rubber)
—now Industrial Adviser (Che-
micals), Development Wing, Min-
istry of Commerce & Industry.

4. Originally, the Office Memorandum stated that the Committee was to submit its report within a period of four months from the date of the Notification, i.e., by 10th February, 1961. The Committee found it difficult to adhere to this time schedule due to many reasons. In the first place, it took considerable amount of time for collection of the necessary data. Secondly, very little was known in India about the scale on which production of petro-chemicals should be organised. A large number of complex problems had to be studied and the Chairman and the other members of the Committee had to devote their time to other work as well in the discharge of their normal duties. In view of these reasons, it was considered that the time at the disposal of the Committee was inadequate and extension of the date for submitting the report to 31st December, 1961 was, therefore, sought and obtained.

Brief Account of the Committee's work

5. The committee held its first meeting in New Delhi on 18th November, 1960. Since the Committee would take some time to submit its report, a point was raised whether an agreed recommendation to the effect that applications for licence under the Industries (Development & Regulation) Act in respect of petro-chemical industries, which had already been received and which might be received before the submission of the Report, could be considered on merits and licences issued in respect of reasonable proposals which *prima facie* deserved favourable consideration. No decision was taken on this point since the opinion was divided. It was decided to issue a questionnaire (Appendix III) to the oil refineries to facilitate collection of necessary information. It was also decided to draw up a list of petro-chemical products whose manufacture should be taken up in the first instance. It was also decided that experts in the field and other interested parties who wanted to meet the Committee and place their views before it should be invited to do so.

The second meeting of the Committee was held on 10th February, 1961 at Bombay. The representatives of firms who had indicated their desire to meet the Committee to enable them to put forward their views with regard to the development of organic chemicals derived from petroleum products and who had accepted the Committee's invitation, had discussions with the Committee. The Committee held separate discussions with the representatives of different firms.

The third meeting of the Committee was held in New Delhi on 25th April, 1961. At this meeting, on behalf of the Organic Chemicals Panel of the Development Council for Organic Chemical Industries, a few members of the Panel met the Committee. They discussed with the Committee desirable targets for a number of heavy organic chemicals during the Third and the Fourth Five-Year Plan periods. They also apprised the Committee of the tentative estimates arrived at for the organic chemicals, plastics and other related products.

Seven further meetings of the Committee on the dates indicated below were held in Delhi to review the draft Chapters of the Committee's Report :

Fourth meeting	on	6-9-61
Fifth meeting	on	18-9-61
Sixth meeting	on	21-9-61
Seventh meeting	on	22-9-61
Eighth meeting	on	27-9-61
Ninth meeting	on	28-9-61
Tenth meeting	on	24-10-61

The committee at its eleventh meeting held on 14th December, 1961 approved the final Report which was submitted to Government on 26th December 1961.

A list of persons with whom the Committee had discussions is at Appendix IV. The Committee would like to place on record its appreciation of their helpful attitude and the readiness with which they made available to the Committee the information at their disposal.

Report—Method of Presentation

6. Subsequent chapters in this Report deal in some detail with the development of Petro-chemical Industry in U.S.A., West Germany, U.K., Japan, France and Italy; with the availability of raw material feed-stocks for the manufacture of nitrogenous fertilizers, organic chemicals and related products; the extent to which the organic chemicals and other products are to be based on petroleum and non-petroleum feed-stocks; facilities needed for the manufacture of organic chemicals and related products etc. A summary of the major recommendations is in the last Chapter.

CHAPTER II

A BRIEF REVIEW OF THE DEVELOPMENT OF PETRO-CHEMICAL INDUSTRY IN ADVANCED COUNTRIES

As is well-known, during the past few years Chemical Industry in advanced countries is growing at a much faster rate than the industry in general; the rate of expansion of the Petro-chemical industry in particular has surpassed that of the Chemical Industry as a whole. Significant technological and other developments, which are having far-reaching consequences in the field of Petro-chemical Industry, have taken place in recent years and further developments are in progress at the present time. As a consequence of these rapid changes, new products are being put on the market and while some of them are supplementing some of the conventional older products, others are cutting into their use. As none of the members of the Committee has a first-hand knowledge of these recent developments, the material presented in this Chapter has been collected from published material.

U.S.A.

The Petro-chemical Industry, which came into being in the U.S.A. nearly 40 years ago, made great headway during and particularly since the World War II so much so that today the largest output of petro-chemicals is from the U.S.A. It is stated that last year the American Petro-chemical Industry produced 22 million metric tons of products. This is stated to signify a five-fold increase as compared to the production at the end of World War II and a three-fold increase as compared to the production in the beginning of the last decade. The production of petro-chemicals in U.S.A. in 1960 accounted for about 30% of the total volume and about 50% of the Dollar value of all chemicals manufactured in that country. It is stated that this enormous production of petro-chemicals absorbs only about 2% of the total amount of crude oil and about 1 to 2% of marketed natural gas. At present, it is understood that 85% of the total U.S. production of aliphatic and aromatic organic chemicals is derived from oil and natural gas with the balance being derived from coal and agricultural sources. It is stated that nearly 80% of the petro-chemicals (derived from petroleum and natural gas) goes into the production of plastics, paints, detergents, synthetic rubber, synthetic fibres, agricultural chemicals and automotive chemicals :

"Of the \$3,000 million investment in the new chemical plant now (July, 1960) under construction, over \$1,840 million or 61% is to be spent on basically petro-chemical facilities. Thus, the continued massive expansion of the country's petro-chemical potential is in prospect."

It is anticipated that in five-years time the rate of production of petro-chemicals in U.S.A. will reach 40 million tons per year and that this would constitute about 40% of all chemicals produced then in that country.

About 75% of the petro-chemical plant capacity in the U.S.A. is concentrated in the Gulf and East Coast areas. The major petro-chemical centres are Texas and Louisiana and these are also the main locations of oil-refining and natural gas operations.

The current practice in U.S.A. is generally for the oil company to supply the basic raw materials to the chemical companies which process them into finished products. Of late, two other trends are also discernible; a number of oil companies themselves are undertaking the manufacture of chemicals and other products. For example, Shell manufactures epoxy-resins, synthetic rubber and agricultural chemicals; Jersey and California Standard make polypropylene, butyl-rubber, lube additives and fertilizers. On the other hand, well-known chemical companies, such as Union Carbide, Dow and Celanese are undertaking the processing of natural gas, LPG, purchased refinery gases and naphtha to make themselves less dependent on oil companies for their chemical-base stock. It is stated that while the leading chemical companies supply 50 to 65% of the total sales of petro-chemicals in U.S.A., the share of the leading oil companies amounts to about 10—15%.

Many American petro-chemical concerns have set up petro-chemical plants in European countries either by independent investment or by joint ventures. Thus, both American capital and technical knowhow has been made available in Europe, the participation of U.S. petro-chemical firms in Europe is indicated below :

<i>Companies</i>	<i>Countries</i>
Jersey	U.K., France, Germany, Belgium Holland, Spain.
Dupont	U.K., Holland.
Carbide	U.K., Belgium, Italy.
Monsanto	U.K., Italy, Spain.
S.O. of California (Oronite)	U.K., France.
S.O. of Indiana (Amoco)	Belgium.
Texas Butadiene	France, Sweden.
Dow	U.K., Holland, Italy, Spain.
Goodrich Chemical	Holland.
Olin Mathieson	Belgium.

It is stated that Jersey Standard has so far invested 150 million Dollars in six European countries.

It is stated that the major chemical companies spend about 3 to 5% of their sales turn-over on research and development.

It was in the late 1940s when adequate refining facilities had been established in Europe that the large-scale petro-chemical plants were set up there. It is stated that during the last five years Western Europe's petro-chemical potential has increased five-fold. While in the U.S.A. over 80% of the total organic chemicals produced in that country at present is derived from petroleum hydro-carbons, in Western Europe it is about 30%. According to one estimate (by Socony Mobil) in the next ten years in the U.S.A. the production of chemicals from petroleum and gas is expected to increase at an

annual rate of 7–8%. During the same period, while the production of chemicals as a whole in Western Europe is expected to increase at the rate of about 9% per year, the production of chemicals from petroleum and gas is expected to increase at the rate of 15–20% a year.

Source

- (1) "Features of the U.S. Petro-chemical Scene"—Petroleum Press Service, Vol. XXVII, No. 7, (July 1960) pages 250-252.
- (2) "Oil Companies' Stake in Chemicals"—Petroleum Press Service, Vol. XXVIII, No. 7 (July), 1961), pages 250-252.

Organisation of European Economic Cooperation Area

The production of primary organic petro-chemicals in the O.E.E.C. area increased from 400,000 tons (in terms of carbon content) in 1955 to 1.8 million tons (in terms of carbon content) in 1960. The corresponding quantities of liquid and gaseous petroleum hydro-carbon feed-stocks consumed are estimated at 1.3 million tons in 1955 and 5.8 million in 1960. It is estimated that by the end of 1962 the petro-chemical industries' productive potential would increase to about 3 million tons per annum (carbon content). This level of production would need petroleum hydro-carbon feed stocks to the extent of nearly 11 million tons per annum. This forecast is based on the Petro-chemical Investment Programme for the period 1960-62. Petro-chemical production and capital investment in the countries of the O.E.C. are tabulated below:—

	Petro-chemical Production '000 metric tons (carbon content)				Capital Investment (\$ million equivalent)		
	1957	1958	1959	1960*	To end 1958	To end 1959	To end 1960-61
United Kingdom ..	274	302	385	480	265	347	206
West Germany ..	166	246	362	n.a.	263	343	142
France	80	118	186	280	84	137	250
Italy	73	82	164	n.a.	123	178	239
Netherlands	37	50	56	90	23	n.a.	n.a.
*TOTAL ..	630	813	1160	1,800	775	1050	750

*Provisional estimate.

† Includes other countries like Belgium, Denmark, Spain, from 1958.

Source

- (1) "Massive Expansion of Petro-chemicals"—Petroleum Press Service, Vol. XXVIII, No. 3 (March, 1961)—page 108.
- (2) "Western Europe's Petro-chemical Boom"—Petroleum Press Service, Vol. XXVII, No. 2 (February 1960)—pages 66–67.

West Germany

Even prior to World War II Germany had built up a flourishing Organic Chemical industry based principally on the products of coal carbonisation. This was due to the fact that Germany had rich deposits of coal but little or no oil. Even prior to the division of Germany, the Organic Chemical Industry had largely been concentrated in those areas which constitute West Germany today.

As against the domestic output of 5 million tons of crude oil in 1959, the oil consumption was about 20 million tons. Large quantities of imported crude oil are processed in the new refineries which were set up in West Germany since 1953. It is expected that the refining capacity would increase to about 45 million tons in 1961 and to about 54 million tons in 1965.

The non-availability of crude oil coupled with the flourishing Organic Chemical Industry based on coal-tar products delayed the development of the Petro-chemical Industry in Germany till the setting up of a large number of refineries based on imported crude oil. The chief reason for the development of Petro-chemical Industry in West Germany is the need for olefines (which could not be obtained in sufficient quantities at reasonable prices from coal-tar products) required for the manufacture of plastics and synthetic fibres. Since 1958 the Petro-chemical Industry in West Germany has made rapid progress and in 1959 out of a total production of 1,348,000 tons of primary organic chemicals nearly 60% was derived from coal chemicals and 40% from petroleum chemicals, as can be seen from the following table:—

Consumption of Primary Chemicals for Organic Synthesis

(in Thousand Metric Tons)

	From Coal Chemicals			From Petro-Chemicals			Total		
	1957	1958	1959	1957	1958	1959	1957	1958	1959
Carbon monoxide ..	223	210	258	34	80	107	257	290	365
Methane ..	—	—	—	13	16	13	13	16	13
Butane ..	—	—	—	—	10	—	—	10	—
Acetylene ..	126	176	167	59	64	80	185	240	247
Ethylene ..	37	40	34	38	59	131	75	99	163
Propylene ..	—	—	—	40	60	81	40	60	81
Butylene ..	—	—	—	10	13	23	10	13	23
Butadiene ..	—	—	—	—	17	34	—	17	34
Aliphatic hydrocarbons C ₃ & C ₅ +	14	4	5	2	4	37	16	8	42
Benzene ..	185	220	256	—	—	—	185	220	256
Toluene ..	17	14	2	3	4	23	20	18	25
Xylene ..	6	7	3	—	—	6	6	7	9
Naphthalene ..	67	76	88	—	—	—	67	76	88
TOTAL ..	675	747	813	199	327	535	874	1,074	1,348

It is stated that West Germany occupies the fourth place in the world of chemical production, the first, second and third places going to the United States, Soviet Union and Great Britain respectively. It is estimated that the current output of chemicals in West Germany is worth over \$5 billion.

The demand for benzene for the Chemical Industry has outstripped the domestic output. It is stated that as against the current demand of about 350,000 tons of benzene per year the domestic availability is only to the extent of 250,000 tons per year. This has necessitated imports of about 100,000 tons of benzene in 1960 and it is estimated that the need for imports might increase in the coming years. In order to correct this imbalance the possibilities of producing benzene from petroleum sources are being explored. The position with regard to naphthalene is somewhat similar. All the naphthalene needed today is being obtained from coal chemicals and it is likely that petroleum based naphthalene might be produced eventually. Some quantities of O-xylene, which could be used in place of naphthalene for the production of phthalic anhydride, are already being produced from petroleum sources.

The Oil Industry in West Germany has limited its activities to the supply of raw materials, like ethylene, propylene etc., to the Organic Chemical Industry. In certain cases, the Oil Industry has established joint enterprises with chemical producers for the manufacture of petro-chemicals. The following four leading chemical companies account for nearly 75% of the total production of petro-chemicals in West Germany:—

Badische Anilin-und Sodafabriken, Farbenfabriken Bayer, Chemsche Werke Huels, and Farbwerke Hoechst, respectively, by the joint ventures Erdoel-chemie (Bayer/BP), and ROW (BASF/Shell).

The remaining capacity is operated mainly by

Phenolchemie, Rohm & Haas, Wacker-Chemie, Rheinpreussen, Celserberg-Benzin, Union Rheinische Braunkohlen and Kraftstoff A.G., and Ruhrchemie.

In 1959 ROW had a capacity of 50,000 tons of high pressure polyethylene, 6,000 tons of Phillips low-pressure polyethylene and 12,000 tons of ethyl-benzene. It is stated that the expansion plans will eventually increase the capacity of ethylene to 125,000 tons for the production of 100,000 tons of high-pressure and 12,000 tons of low-pressure polyethylene in 1962. It is stated that for the production of high-purity ethylene, an ethylene plant with a capacity of 75,000 tons will be constructed. ROW have also undertaken the production of 2,000 tons of Epoxy-resins per year. It is stated that "investment for the complete projects of ROW will amount to \$120 million."

Erdoel-chemie, which started operation at the end of 1959, has a capacity for processing 265,000 tons of light gasoline—65,000 tons by Sand-cracker and 200,000 tons by a Stone & Webster steam-cracker. Erdoel-Chemie has a capacity of about 45,000 tons ethylene, 40,000 tons propylene and 31,000 tons C₄ hydro-carbons besides tail

gases. This company processes these primary products into finished products. It is estimated that investment up-to-now would be of the order of \$60 million.

Farbwerke Hoechst, a leading chemical and petro-chemical manufacturing concern, has also developed special methods for processing crude oil. Their process is stated to consist essentially of high-temperature pyrolysis of gaseous and liquid petroleum hydro-carbons. This company has a combined capacity for the production of 70,000 tons of acetylene, ethylene and propylene by high-temperature pyrolysis. The capacities for polyethylene and polypropylene are of the order of 24,000 tons and 6,000 tons respectively. Hoechst are one of the main producers of vinyl-plastics. Vinyl-chloride is still being produced from acetylene and hydrogen-chloride. The possibilities of vinyl-chloride being produced from ethylene are receiving greater attention.

Chemische Werke Huels had a four-step butadiene process the starting material being acetylene. Buna-werke Huels has now replaced this by the dehydrogenation of N-butane obtained from the Petroleum Industry by the Houdri dehydrogenation process. In 1958, Huels had an initial capacity of 45,000 tons of cold rubber for the production of which 30,000 tons of butadiene and 12,000 tons of styrene were needed. It is stated that the production of this variety of rubber would soon reach 120,000 tons/year.

It is anticipated that the further growth and development of the Organic Chemical Industry in West Germany would continue to depend on both coal-chemical and petro-chemical raw materials. Based on the present growth rates it is anticipated that by 1962 West Germany might produce one million tons of coal-chemical raw materials and an equal quantity of petro-chemical raw materials. It is also anticipated that West Germany would maintain her position as the second leading petro-chemical producing nation in Europe.

Source

"Petro-chemicals in West Germany"—Oil and Gas International (June 1961)—pages 42-45.

United Kingdom

Like Germany U.K. also had built up a large Organic Chemical Industry based primarily on the coal carbonisation products in the interval between the two World Wars. Up to the outbreak of World War II practically no chemicals were manufactured from oil in the United Kingdom. The choice of the source of the raw material was governed by the abundant availability of coal and non-availability of oil on the one hand and the duty levied on imported hydro-carbon oil on the other. The realisation of the future importance of the Petro-chemical Industry led to the removal of the duty on imported hydro-carbon oils used in chemical synthesis on the basis of the recommendations of the Ayre Committee (1944). Since then the Petro-chemical Industry has made spectacular progress in U.K. The expanding Petro-chemical Industry in U.K. today not only satisfies almost all domestic requirements but also leaves a large surplus on which a thriving export trade has been built.

Of all the major manufacturing industries in Britain, the Organic Chemical Industry, together with the industries converting organic chemicals into end-products such as plastics, detergents, synthetic rubber, shows the most dynamic growth rate. The growth rate of the Petro-chemical Industry in relation to growth rates of other industries for the period 1948-1958 illustrates this point:

TABLE I

	Average annual growth rate in terms of production per cent per annum for the period 1948-58.
Total all industries	3.2
Total all chemicals .. .	6.9
Chemicals (including plastics, from petroleum) .. .	46.5
Plastics from all sources .. .	16.2
Vehicles	6.2
Food	3.1
Textile	0.2
Paper, printing and publishing	5.6

The Petro-chemical Industry in U.K., as in other countries, has developed near the ports because of proximity to the refineries and facilities available for transportation of raw materials as well as finished products. Petro-chemical plants have been built in many cases at the sites of the refineries.

The estimated total production of organic chemicals and the extent to which they are derived from different raw material sources are given below. Raw materials from petroleum sources, which account for the production of about 6% of the total organic chemicals in 1949 increased to 51% in 1959 and it is estimated that this would go up to 65% by 1962:

TABLE II

Production of Organic Chemicals in the United Kingdom

(Thousand metric tons)

Sources	1949	1953	1955	1959	1962
Coal-tar	173	230	275	365	540
Acetylene	70	80	110	135	150
Synthesis gas	55	70	80	95	90
Fermentation	160	170	150	80	30
Petroleum	30	200	290	700	1500
TOTAL	490	750	895	1,375	2,310

The rapid expansion in the output of organic chemicals is largely due to increased production of ethylene, propylene, butadiene and benzene and their conversion to polyethylene, synthetic rubber, styrene, synthetic detergents and synthetic fibres.

The rapid increase in output of petro-chemicals (organic as well as inorganic in the U.K.) together with the petroleum feedstock and total investment are shown below :

TABLE III
Production of Chemicals from Petroleum in U.K.

	Production (Thousand Metric Tons)		Petroleum Feed- stock (Thousand metric ton)	Total † invest- ment year end; \$million
	Organic chemicals	Inorganic chemicals*		
1950	45	15	160	N.A.
1951	90	27	300	N.A.
1952	150	36	500	N.A.
1953	195	60	660	113
1954	250	75	800	122
1955	290	90	900	125
1956	330	110	970	170
1957	435	130	1,280	212
1958	475	160	1,490	265
1959	595	245	2,850	347
1960(est.)	750	295	2,350	395
1962 (est.)	1,400	300	4,290	553

* Carbon black, amonia and sulphur.

† Organic Chemicals only.

Table IV summarises the major operations of the important joint companies in Britain in the field of petro-chemicals :

TABLE IV
Production of Primary Petro-chemicals
(capacity in 100 metric tons)

Company	Ethylene	Propylene	Butadiene	Polyethylene
British Hydro-carbon Chemicals Ltd. ..	130	110	10	11
Imperial Chemical Industries Ltd. ..	120-140*	80	14*	90-105*
Shell Chemical Co Ltd. ..	80*	80*		15**
ESSO Petroleum Co. Ltd. ..	40		42	
Union Carbide Ltd. ..				11.5-25*
Monsanto Chemicals Ltd. ...				10-20*
Courtaulds Ltd. ..	15-21*	7-10*		

*Total after complete expansion.

**Polyethylene and Polypropylene.

Sources :

- (1) "The Petroleum Chemicals Industry" (Second Edition—1958) Spon, by R. F. Goldstein.
- (2) "Petro-chemicals in Britain" by Harold P. Hodge—Chemical Engineering Progress, Vol. 57, No. 2 (February 1961)—pages 37-42.
- (3) "The future of Chemicals from petroleum"—Fifth Ivan Levinstein Memorial Lecture by L. H. Williams, Chemistry and Industry (August 6, 1960), pages 1,006-1,014.

JAPAN

Japan's young petro-chemical industry is growing up at an impressive rate. It came into being only in 1957 when secondary butanol and MEK were made from refinery gas. Prior to this development, her organic chemical industry was based largely on acetylene from carbide, coke-oven gas and coal-mine gas. Dry natural gas which is not associated with oil was first used by the Japan Gas Chemical Company in 1952 for making methanol. Now it is being mainly used for the production of methanol and ammonia.

Japan's actual and estimated petro-chemical consumption is given in the table below :

TABLE I
Actual and Estimated Petro-chemical Consumption
(Thousand Metric Tons)

Products	1958	1959	1960	1965	1970
Ethylene	14	44	84	320	510
Propylene	3	10	25	240	470
Butylene*	3	7	49	190	360
Benzene	66	92	130	240	370
Toluene	22	45	56	100	140
Xylene	10	20	52	120	190

*The butylene estimates should be interpreted as the butylene equivalent of butylene, butane and of butadiene extracted directly from cracked hydro-carbon streams.

The estimated production of Japan's major petro-chemical products in 1960 is given below :

TABLE II
(in Metric Tons)

Product	Output
Acetaldehyde	35,000
Acetylene	52,000
Acrylonitrile	24,000
Aromatics	70,000
Carbon Black	44,000
Ethylene	125,000
Ethylene glycol	16,000
Ethylene Oxide	9,000
Polyethylene	70,000
Polypropylene	55,000
Polystyrene	15,000
Styrene monomer	25,000
Synthetic rubber (SBR)	239,000

The present and planned capacities together with the number of plants for production of major products are given in the following table :

TABLE 'III
Present and planned Capacities
(Thousand metric tons)

	No. of plants	Capacity	
		Present	Planned
Ethylene	21	79	565.3
Propylene	15	63.5	348.6
Butylene (Equiv.)	14	66.6	212.7
Benzene	9*	109.5	61.5
Toluene	7*	47.4	50.4
Xylene	7*	32.8	33.5
Methanol	17	207.9	229.0
Formalin	18	204.1	60.0
Calcium Carbide	26	1,887	53.0
Acetylene (petroleum)	5	—	48.8

Petro-chemical plants are located throughout Japan, the heaviest concentration being around Tokyo. The bulk of benzene still comes from coal-carbonisation and imports. Three companies have UDEX units in operation and many more are planned. Methanol, which used to be made exclusively from water gas till 1951, is now made from natural gas to the extent of 64% of the total production. Acetylene, which used to be obtained from calcium carbide, is likely to be obtained in increasing quantities from petro-chemical sources due to shortage of power and its rising costs. Some of the acetylene-based products are expected to shift to other methods of production, when ethylene and propylene become available at reduced prices.

The growth and development of petro-chemical industry in Japan is regulated in accordance with the plans approved by the Light Industries Bureau of MITI (Ministry of Internal Trade & Industry). In December, 1959 this Bureau published a statement of its "Policy on Petro-chemical Industrialisation Plan", the main objective of which was to modernize the Chemical Industry as a whole. During 1962 MITI expects Japan to not only produce chemicals at prices equivalent to international c.i.f. prices but also attain self-sufficiency. This is regarded as an ambitious goal by some observers. Of late the market prices of petro-chemical products have been showing a downward trend, but their prices are still about 50% higher than in American markets. Japan expects to reduce the cost of production by expanding the production capacity of each plant and "by selecting from the latest available processes and integrating operations to balance out petro-chemical production and derivatives".

The first phase plan of Japan's petro-chemical industry was completed in 1960 and required an investment of about \$256 million.

The foreign exchange saving during the years 1957-59 has been estimated as :

1957	\$ 4.7 million
1958	\$ 28.6 "
1959	\$ 69.5 "

Plans already under-way indicate that plant investment in the Second Five-Year programme may well exceed \$ 300 million.

Japan's organic chemical products have not been a major factor in world markets. So far, Japan has been able to export only fertilizers and PVC. It is stated that "her low labour costs which are important in manufacturing activities do not off-set relatively, and in some cases artificially, high chemical raw material costs". Japan may, therefore, not be in a competitive position in the world markets for some years to come. Till recently, the production of almost all the plants was dependent on foreign techniques. "The techniques of I.C.I. and BASF are used in the low-density plants, Phillips and Standard Oil of Indiana for medium-density and Ziegler for high-density polyethylene plant." This was inevitable, as Japan aimed at building up her Petro-chemical Industry as quickly as possible. However, some of the chemical companies have intensified their research and development programmes and it is stated that they have developed their own processes which have found industrial application.

Sources :

- (1) "Japan's two petro-chemical industries" by Hugh S. Pylant—Oil and Gas International (January 1961), pages 47-48.
- (2) "Present Status of the Petro-chemical Industry in Japan" by Tozo Amemiya—Bulletin of the Japan Petroleum Institute, Vol. 3 (March 1961), pages 83-88.
- (3) "Japanese Petro-chemical Industry sets some ambitious goals" by Arthur M. Griswold and Shiro Ishihara—Oil and Gas International (August 1961), pages 46-50.

FRANCE

Petro-chemical Industry in France is hardly ten years old; it came into being in early 1950s. Although this industry in France is expanding at a rate much faster than any other major European country, the total output is still behind those of U.K. and West Germany. The French natural gas production has increased from 266.5 million cu. metres in 1952 to 4,548 million cu. meters in 1960. While the French crude petroleum production has increased from 0.35 million tons in 1952 to 11.4 millions tons in 1960, the refining capacity over the same period has increased from 21.5 million tons to 32.9 million tons. It would thus be seen that out of the total tonnage of crude petroleum treated in refineries about a third is met from crude petroleum produced within France, the rest being met from outside sources.

In the beginning, as in U.S., France was not in a position to rely on refinery gases for olefines, because most of the

refineries in France were small and had very little catalytic cracking capacity. For ethylene and propylene the French, therefore turned to steam-cracking of light naphtha. The present indications are that this process will continue to supply these basic chemicals in France. The present capacity of ethylene is estimated at 307 million lbs. and 84% of this is based on naphtha-cracking, the remainder coming from the coke-oven gases. Ethylene capacity is expected to increase to 472 million lbs. by 1963. Out of this total output 78% would be from naphtha-crackers, 12% from natural gases and 10% from coke-oven gases.

Demand for some important primary raw materials is given below :

TABLE I

		(In million lbs.)	
		1959	1965
Ethylene		130	545-645
Propylene		195	350-335
Benzene		280	600

The following figures give the existing and planned facilities for the manufacture of chemicals (organic as well as inorganic) from petroleum hydro-carbons :

TABLE II
Estimated Annual Production Capacities

		(Thousand metric tons)	
		End of 1960	End of 1963
Olefines		334	513
Butadiene		9	106
Aromatics		55	157
Carbon Black		45	95
Ammonia (expressed as N ₂)		380	45
Sulphur		790	1,283

Significant developments are expected to take place in the consumption pattern of rubber and synthetic fibres over the next few years in France. The consumption of rubber is anticipated to increase from 192,000 tons in 1958 to 280,000 tons in 1965. The proportion of synthetic rubber consumption is expected to increase from 29% in 1958 to 61% in 1965 :

TABLE III
Estimated rubber Consumption

		1958		1965	
		M.M. ton	%	M. M. ton	%
Synthetic		55	29	170	61
Natural		137	71	110	39
TOTAL		192	100	280	100

The rapid rate at which the synthetic fibre production is expected to increase is illustrated by the following table. The percentage of synthetics to all textiles is expected to rise from 6.1% in 1959 to 18% in 1965. The per capita consumption would increase from about 1.6 lbs. in 1959 to about 5.0 lbs. in 1965:

TABLE IV
Synthetic Fibre Production

	Est. production (Million lb.)		Est.* ca- pacity (Million lb.)
	1959	1965	
<i>Synthetic Fibre</i>			
Nylon	47	125	100
Polyester	20	65	45
Acrylic	5	35	20
Polypropylene and others	—	10	
Total synthetics	72	235	165
Total textile market**	1,184	1,335	
% synthetics of total textiles	6.1	18	

* On stream, under construction, or planned.

** Includes wool, cotton, rayon and acetate and the synthetics.

The French chemical industry is more or less evenly distributed in several areas near the boundary regions of the country. The main petro-chemical plants are in the South near the large refining centres in Basse Seine district and in the Lacq region where major natural gas reserve was discovered in 1949. The two important factors which have influenced the location of petro-chemical plants are:

- (a) nearness to the raw material source (which cuts down the transportation cost); and
- (b) utilization of unwanted by-products of chemical manufacture by refineries.

"With the exception of the enterprises at Lacq, most of the French petro-chemical industry is dominated by the oil companies via the joint venture route, although companies such as ESSO and C.F.R. make considerable merchant sales of basic petro-chemicals."

Since the discovery of gas in the Lacq area in Southern France that area is rapidly becoming a major petro-chemical centre. Lacq gas, which is predominantly methane, contains a high percentage (12%) of H_2S , the other ingredients being ethane, propane, butane and natural gasoline, all of which can be used for petro-chemical purposes. H_2S is removed from natural gas in order to make it fit for chemical and household purposes. Sulphur is being produced from H_2S . A carbon black plant having a capacity of 25,000 tons/year based on the natural gases is under construction. A number of other plants are now under construction, which will produce

acetylene (for acetaldehyde and vinyl-chloride), ammonia and methanol (100 tons per day initial capacity). The construction of a plant for the production of ethylene from ethane is nearing completion (capacity 25,000 tons per annum of ethylene). The C^4 stream which is rich in natural butane is likely to be used for the manufacture of butadiene. The natural gasoline, which contains about 13% toluene and 25% mixed xylenes may be used for the production of aromatics.

Sources :

- (1) "Petro-chemicals show top gain in France" by F. A. Escherich—Oil and Gas International (July 1961), pages 44-48.
- (2) "French Petro-chemical Industry Mushrooming" by Maurice Moulin—Oil and Gas Journal (July 10, 1961), pages 133-135.

ITALY

As in France, the Petro-chemical industry in Italy had a rather late start. The building of a steam-cracking unit by Montecatini at Ferrara in 1950 for the production of olefines for conversion to plastics, plasticizers and solvents marks the beginning of the Petro-chemical Industry in Italy. Since then, this industry has made very rapid progress in that country. At Mantua, the Edison plant, another steam-cracking plant (capacity: 25,000 tons/year of ethylene and equivalent amount of propylene), is in operation. Other plants are expected to be in operation in central Italy soon.

At present, Italy is regarded as the fourth largest chemical producers in Western Europe. The rapid expansion of the Organic Chemical Industry in Italy is illustrated by the table below:

TABLE I
CHEMICALS — Production figures of Basic Organic Products in Italy.

	1957 (million pounds)	1958	1959
Acetic acid	61	77	77
Acetone " " " " " "	9	8	9
Phenol " " " " " "	22	33	24
Methanol " " " " " "	86	97	106
Formaldehyde (100%)	46	44	53
Urea " " " " " "	198	237	261
Plastics " " " " " "	328	396	557
Synthetic Rubber " " " " " "	—	44	106
Organic Dyestuffs " " " " " "	29	24	33

Table II shows the petro-chemical production in Italy in terms of carbon content :

TABLE II
Petro-Chemical Production in Italy

							(in terms of Carbon Content)		
							Tons of Carbon	Index	Increase % year
1954	..	..	..	..	..	..	16,000	100	—
1955	..	..	..	..	..	..	26,000	162	62
1956	..	..	..	..	..	..	38,000	237	46
1957	..	..	..	..	..	..	73,000	465	92
1958	..	..	..	..	..	..	130,000	812	78
1959	..	..	..	..	..	..	180,000	1,125	38

At Brindisi in South Italy, Montecatini are establishing a new petro-chemical complex, the planned capacity of which would be 1,500,000 tons of crude oil per year. This new plant is expected to be one of the most important of its kind in Europe. "Olefins, polymers and co-polymers (polyethylene, iso-tactic polypropylene, polybutylene, polybutadiene); and a wide range of chemical products for industry such as solvents, aldehydes, alcohols, plasticizers, etc., will be produced at this installation."

24,000 tons per year of low-density polyethylene is being produced at Montecatini's Ferrara plant. This production is expected to increase to 30,000 tons/year, when the Brindisi facility is completed. Montecatini were the first to produce polypropylene and it is at their Ferrara plant that Montecatini produced the first commercial "Iso-tactic" polypropylene in 1957. This plant is stated to have a capacity of about 30,000 tons/year. Another plant for the production of poly-propylene is now under construction in Brindisi. Montecatini now produce practically all the plastics at present on the market.

The largest chemical centres of the Edison group are at Porto Marghera (Venice), Mantova (Po Valley) and Priolo (Sicily). At the first two centres a wide range of products such as PVC, polyvinyl acetate, polystyrene, acrylonitrile and plasticizers are produced. This group's Sicilian plants are regarded as typical example of integrated petro-chemical production. "One of the two plants is principally engaged in the production of various fertilizers and olefins, which are subsequently utilized in the second plant for manufacture of polyethylene and a series of olefin derivatives." ANIC (Azienda Nazionale Indrogenazione Combustibili), a company belonging to the State enterprise ENI (Ente Nazionale Idrocarburi), has been producing petro-chemicals at Ravenna since 1959 using natural gases available nearby. This gas is nearly pure methane. Methane is converted via acetylene to butadiene which is then converted to styrene-butadiene rubber (SBR). A new plant for conversion of butane to butadiene has been recently added. The total synthetic rubber capacity is stated to be over 90,000 tons/year. ANIC's production of nitrogenous fertilizers is over one million tons per

year. A new Urea plant is now in operation. At Ravenna, a carbon black plant (Phillips Carbon Black Italiana) is under construction.

One of Italy's major problems was lack of adequate power for industry. Italy's coal deposits are meagre. Only low-grade lignite is available in limited quantities. Italy's oil resources being poor, much of the refining capacity is based on imported crudes mainly from the Middle East. The Discovery of large gas reserves in Po Valley helped solve this problem to a considerable extent. The Po Valley gas pipeline network is stated to total a length of 3,280 miles. Natural gas price is the same at all consuming centres irrespective of their distance from the production areas, and the price has been fixed by "pegging the price per calorie of natural gas to the price of per calorie of fuel oil" which had been the cheapest Italian fuel. Availability of large quantities of cheap natural gas has made the products of Italian industry competitive with the products of other European countries.

The development of petro-chemical industry in Italy has made a notable contribution to the increase in Italy's foreign trade. This industry is regarded as being in an extremely good position owing to the fact that it is in the hands of well-equipped companies supported by adequate research programmes.

Source :

- (1) "Italians set new horizons for Chemical Industry" by Bartolomeo Orsoni and Mario Ottolenghi—Oil and Gas International (May 1961), pages 40-43.
- (2) "ENI—A dynamic holding company" by John C. Reider—Oil and Gas International (February 1961), pages 16-19.

General

The modern tendency of undertaking the establishment of large integrated petro-chemical complexes are illustrated by the two examples given below :

- I. "MONSANTO CHEMICAL CO., Addyston, near Cincinnati is building a new plant with 50,000,000 lb. per year, capacity of styrene-based plastic materials. Completion stated late 1961. Styrene monomer will come from Texas City.

In Gloucester County, New Jersey, Monsanto is building a phthalic-anhydride plant and a 20,000,000 lb. per year benzyl-chloride plant. Completion early 1962.

At Chocolate Bayou, near Alvin, Tex., Monsanto will complete a big complex in 1962, with Bechtel Corp. as prime contractor. In addition to ethylene capacity of 500,000,000 lb. per year, the plant will have 42,000,000 gal. per year capacity for benzene, 50,000,000 lb. naphthalene, and unannounced amounts of propylene, cumene, phenol, acetone, ethyl benzene, oxo-alcohols and others.

At Taxas City, Monsanto's programme includes completion of a new phenol plant spring 1962, with capacity of 50,000,000 to 75,000,000 lb. per year. Capacity of vinyl-chloride monomer is being boosted by 50%, with completion by July, 1961. High-pressure polyethylene capacity will be increased 30% with completion early 1962."

(Reproduced from):

'Oil & Gas Journal' (May 26, 1961)—page 68.

- II. "IMPERIAL CHEMICAL INDUSTRIES has decided in principle to establish new manufacturing units in the European Economic Community, among them a complex of chemical plants in the Rotterdam area for the manufacture of petro-chemicals, including plastics and related products. Negotiations for acquiring a 300-acre site near Rotterdam are well-advanced, and construction is expected to begin early next year. It is envisaged that up to £100 million will be spent on the Rotterdam project in the next decade."

(Reproduced from):

'Petroleum Press Service,' Vol. XXVIII, No. 3 (March 1961)—page 113.



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CHAPTER III

AVAILABILITY OF RAW MATERIAL FEEDSTOCKS

Reference to the main sources of starting materials needed for the manufacture of synthetic organic chemicals and related products has already been made in the introductory part of Chapter I. In this chapter, the availability of these raw material feedstocks has been examined.

Ethyl Alcohol

In order to achieve a production target of 30 million gallons of power and industrial alcohol, a capacity target of 36 million gallons was fixed for the Second Plan. Although the capacity of the Alcohol Industry in 1960-61 stood at about 40 million gallons, the production of alcohol in 1960 was only about 20 million gallons. This shortfall in production is mainly because the demand for alcohol did not develop as fast as anticipated due to delay in the implementation of schemes based on alcohol as raw material. Under the Third Plan, based on a sugar production target of 3.5 million tons, a capacity target of 72 million gallons of alcohol to ensure a production of 60 million gallons has been fixed. Out of the expected production of 60 million gallons (about 200,000 tons) of alcohol about 10 million gallons might be required for use in the manufacture of potable spirits and in ordinary denatured spirit. About 50 million gallons of alcohol will, therefore, be available for utilisation as raw material for industries and there should be no difficulty in the utilization of this amount of alcohol by the organic chemical industries as the estimated demand by the end of the Third Plan is over 50 million gallons. It is estimated that by 1970-71 about 90 million gallons of alcohol, corresponding to about 300,000 tons, would be available for the consuming chemical industries सत्यमेव जयते

Benzene, Toluene, Xylene and Naphthalene

The availability of BTX as by-production of coal carbonisation is dependent, amongst other things, mainly, on the quantity of coal which would be carbonised and this in turn is linked to the production of iron and steel. In order to meet the metallurgical coke required to achieve a production target of 9.2 million tons of steel ingots fixed for the Third Plan, it is understood that 17 million tons of coal would be carbonised per year. Assuming that about two-thirds of the tar will be subjected to refining and fractionation for the purpose of BTX-N recoveries, that the yield of crude benzol is 10 litres per ton of coal carbonised, that the yield of pure benzene will be 60% of crude benzol processed and that 4% of hot-pressed naphthalene on coal-tar distilled would be recovered, the amount of BTX-N expected to become available by the end of the Third Plan has been estimated. Estimates for the Fourth Plan are based on the tentative

target of 18-19 million tons of steel ingots envisaged for 1970-71 :

	1965-66	1970-71
	tons	tons
Benzene	50,000	100,000
Toluene	22,000	44,000
Xylenes	4,500	9,000
(as solvent naphtha)		
Naphthalene	12,500	25,000
Tar acids	8,700	17,000

Calcium Carbide

The installed capacity for calcium carbide stood at 34,500 tons on 1st April, 1961. The production of calcium carbide is expected to increase from 10,074 tons in 1960 to about 20,000 tons in 1961. Under the Third Plan in order to achieve a production of 60,000 tons of calcium carbide it has been envisaged to bring into existence a capacity of over 70,000 tons. It is anticipated that about 30,000 tons of calcium carbide would be needed to provide acetylene required for welding and lighting purposes. It is also anticipated that about 30,000 to 40,000 tons of calcium carbide would become available for the production of acetylene needed for the organic chemical & plastic industries. It is anticipated that by 1970-71 the production of calcium carbide might increase to about 120,000 tons per year and out of this quantity 80,000 tons may be needed for providing acetylene for welding and lighting purposes and the balance of about 40,000 tons would be available for production of acetylene for organic chemical and plastic industries.

Natural Gas

In India, natural gas both associated and non-associated, has been found in the Nahorkatiya and Moran oil-fields of Upper Assam. The discovery of oil and gas in the region was made by Assam Oil Co. towards the middle of 1953.

In a report entitled "THE UTILIZATION OF ASSAM GAS" prepared by M/s. Snodgrass Associates for the Burmah Oil Co. Ltd., it has been indicated that the solution/associated gas will be separated from the oil by pressure reduction in five stages. Typical analysis of the gas from each separator are shown in the following table :

Gas collected from	1st stage separator controlled at 900 psi	2nd stage separator controlled at 200 psi	3rd stage separator controlled at 70 psi	4th stage separator controlled at 30 psi	5th stage separator controlled at 12 psi
Gas/Oil Ratio	815	220	100	55	20
(Cubic Feet/Bbl) ..	%	%	%	%	%
Methane	90.40	76.63	62.61	42.72	14.75
Ethane	5.08	11.60	15.82	24.64	20.80
Propane	2.84	8.20	13.90	20.45	41.50
Iso-Butane	0.47	1.24	2.82	3.86	8.19
N-butane	0.66	1.51	3.52	5.59	8.86
Iso-pentane	—	—	0.47	1.02	2.01
N-pentane	0.55	0.82	0.52	1.14	2.15
Hexanes plus carbon dioxide	Nil	Nil	Nil	Nil	Nil
Air	Nil	Nil	Nil	Nil	Nil
Specific gravity (Air—1) ..	100.00	100.00	100.00	100.00	100.00
	0.63	0.74	0.78	0.06	1.42

Typical analysis of non-associated gas also taken from the Snodgras Report are shown in the following tables :

TABLE II

Area Well No.	NAHORKATIYA						Moran
	12 Extra (9280 ft)	19 IV II	25 IV	30 9720 ft.	37 6240 ft. (Tipam)	37 7170 ft. (Tipam)	9 19810 ft.
Sp. fr. (Air—1)	0.66	0.63	0.61	0.63	0.57	0.56	0.63
% Gas Volume							
CH ₄	90.17	92.14	95.43	89.95	99.03	99.36	92.53
C ₂ H ₆	5.65	3.54	1.58	5.65	0.59	0.42	2.68
C ₃ H ₈	2.56	1.64	1.26	2.64	0.38		1.85
Iso C ₄ H ₁₀	0.60	0.84	0.59	0.50			0.98
n-C ₄ H ₁₀	0.77	0.79	0.55	0.44		0.22	1.08
C ₅	0.25	1.05	0.59	0.82			
Air	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Co ₂	Nil	Nil	Nil	Nil	Nil	Nil	Nil
	100.00	100.00	100.00	100.00	100.00	100.00	100.00

A tentative assessment of possible availability of natural gas based on DeGoyler and MacNaughton's estimates of proved and indicated reserves as on 1st July, 1960 has been made by the Oil India Ltd. With adequate gas balancing arrangements, quantities available per day for the next 20 years will be as follows :

TABLE III

Year	Total gas solution as-associated Recycle	Fields' Gas Requirement	Surplus gas to be injected into underground storage	Deficit to be made from non-associated gas & storage	Gas available for Market
(1)	(2)	(3)	(4)	(5)	(6)
1962	37	17	10		10
1963	55	20	10		25
1964	64	20	9		35
1965	75	25	5		45
1966	88	30	3		55
1967	102	35	7		60
1968	115	40	15		60
1969	125	40	25		60
1970	135	40	35		60
1971	137	40	37		60
1972	130	40	30		60
1973	105	39	6		60
1974	84	38		14	60
1975	68	37		29	60
1976	55	36		41	60
1977	47	34		47	60
1978	40	28		48	60
1979	35	22		47	60
1980	30	16		46	60
1981	27	10		43	60
1982	25	9		44	60
1983	18	8		50	60

The estimates of gas reserve as on 1st July, 1960 include :

	Proved	Indicated	Total
Solution and Associated Gas	387,816 mm. cft.	146, 184 mm. cft.	534,000 mm. cft.
Non-associated Gas ..	123,366 mm. cft.	43,561 mm. cft.	166,927 mm. cft.
	511,182 mm. cft.	189,745 mm. cft.	700,927 mm. cft.

It may be noted that although the total proved plus indicated reserves of gas are showing a progressive increase, the proved gas reserves are decreasing and indicated gas reserves increasing at the same time. The daily availability figures as assessed by OIL are subject to variation depending upon the behaviour of the field in the course of its development. But it is anticipated that quantities available for market may be then 60 mm.cft.

The latest (June 1961) estimates of recoverable gas reserves presented by M/s. De Goyler and MacNaughton Inc. on behalf of Oil India Ltd. are :

Gross proved reserves:	489,153 million c.ft. at 60°F and 14.7 psia	„
Gross indicated reserves:	251,275	„
	740,428	

Summary of estimated gas reserves as on 1st January, 1961 given by the same firm is presented below :—

TABLE IV

(in MMSCF)

Area	Solution Gas*1		Associated Gas*2		Non-Associated Gas*3	
	Proved	Indicated	Proved	Indicated	Proved	Indicated
Nahorkatiya area ..	150,989	26,735	197,144	21,136	50,406	12,326
Nacholia area ..	22,927	1,460	20,369	—	10,440	18,856
East Nacholia area ..	2,463	1,254	—	—	31,455	9,214
Kathalguri area ..	1,252	2,545	—	—	—	—
Moran Field ..	14,279	35,037	—	42,155	19,211	31,235
TOTAL ..	191,910	80,176	217,513	63,292	111,512	54,631
Total proved gas reserve		520,935				
Total indicated gas reserves		198,099				
		719,034				

*1 Solution Gas : is the gas dissolved in the oil within the formation.

*2 Associated Gas : is the gas associated with significant deposits of oil, e.g., cap gas. For efficient oil recovery, production of this gas is not desirable. After a certain state of depletion it unavoidably gets produced with the oil.

*3 Non-associated Gas : is the gas found in formations having little or no oil.

Fractionation of Nahorkatiya Natural Gas

The Nahorkatiya natural gas can be fractionated to obtain dry lower fractions containing all the methane and most of ethane and higher fractions consisting of propane, butanes, pentanes and higher hydro-carbons. If required, butanes can be separated into normal and iso-butane. If it is assumed that the composition of the gas from each of the five stages remains the same, as indicated on page 23 and the total quantity of gas from all stages fed to the fractionation unit is 892 MMSCFD (produced with about 3 million tons of crude by 1966), first-stage separator gas alone would be 60 MMSCFD. The amount of various hydro-carbons obtainable from 89 m. c.ft. of gas would be as follows:—

	Metric tons per annum	Recovery assumed	
Propane	44,500	Propane	65%
Iso-Butane	14,000	Butanes	90%
n-butane	18,500	Pentanes & Higher	95%
Pentanes & Higher ..	15,000	Operating days in a year for the fractionation unit ..	350

The quantities of lower and higher fractions obtained would depend upon the quantity and composition of the gas fed to the fractionating unit. Both these factors will keep on changing with the production of oil.

The quantities of various hydro-carbons given above are approximate and represent the maximum availability in the initial stages. The design considerations of the fractions unit may exclude gas from one or more separation stages as it may not be economically justified to process gas from all stages. The unit can be largely over-designed so as to handle larger quantities of gas leaner in L.P.G. at later stages of production.

Cambay and Ankleshwar Natural Gas

Both associated and non-associated natural gases have been found in the Cambay area. No indication is however yet available regarding the quantity and the composition of the gases.

Solution/associated gas will be produced also with oil in the Ankleshwar area. It is understood that the gas-oil ratio is of the order of 100m³ of gas per m³ of oil, i.e., about 560 cu. ft. of gas per barrel of oil. About 11 million cu. ft. per day of total gas may be produced with each million ton of crude oil per annum. The representative composition of the gas from different stage separators is not available.

II. Refinery Gases

The gaseous fractions in crude oil or those produced in various cracking or reforming processes may be used as fuel in refinery furnaces; olefines and iso-butane after separation can be used as raw materials for the production of high octane number gasoline components; similarly olefines and paraffins can be used as feed-stocks for production of petro-chemicals.

The availability of these fractions in the gases at the various refineries in India is presented in the table below. The figures have been calculated by averaging the data received from the various refineries in response to a questionnaire (see Appendix III). It may be mentioned that the quantity and composition of the gas obtained from the various refinery units vary according to the operating conditions. The figures given below denote average yields and may not represent an assured supply at a given time. For the public sector refineries of Gauhati and Barauni the design figures have been included :

TABLE V
REFINERY GASES

(in metric tons per annum)

Hydro-carbons	Burmah Shell (Bombay) Refinery- gas total qty. about 80,000 tons p.a.	Stanvac (Bombay) Refinery- gas total qty. about 100,000 tons p.a.	Caltex (VIZAG) Cracking unit Gas total qty. about 16,000 tons p.a.	I.R.L. (GAUHATI) DESIGN Refinery Gas in- cluding all LPG Total qty. about 34,000 tons p.a.	I.R.L. (BARAUNI) DESIGN Refinery Gas in- cluding all LPG Total qty. about 137,000 tons p.a.
Methane	3,400	12,800	300		17,700
Ethylene	1,400	4,300	1,000	12,000	5,600
Ethane	6,500	13,000	2,000		16,700
Propylene	8,000	17,000	3,600	8,500	14,700
Propane	16,000	17,000	1,000		26,700
Butylene	8,300	7,600	1,000	2,000	9,700
Iso-butane			500	4,000	
N-Butane	2,5000	20,000	200	6,000	46,500

STANVAC and CALTEX refineries have polymerisation units which convert a part of the C₃ and C₄ olefines into motor-gasoline component. The rest of the gas is burnt as refinery fuel. Burmah Shell has agreed to sell 50,000 tons of refinery gas to the Trombay Fertilizer Plant. Apart from this, the refineries have indicated that no gas can be made available for outside consumers.

The Burmah Shell and Stanvac refineries produced the following quantities of LPG during 1960 for sale as bottled gas :

Burmah Shell ..	5,800 metric tons
Stanvac	2,250 ,, ,,

The Barauni refinery is designed to produce 20,000 tons per annum of LPG to be sold as bottled gas. The Gauhati refinery is also planning to recover 4,000 to 5,000 tons of LPG.

The Burmah Shell gas-cracker gas contains about 8% by wt. of H₂ S. The quantity of cracked gas currently produced is about 50,000 tons per annum. Over 3,000 tons per annum of sulphur can be obtained from this stream.

Because of its low capacity the quantity of gas produced at the Digboi refinery is too small to be of commercial value.

Naphtha

The surplus of naphtha over the amount used as motor gasoline is available for fertilizer feed-stock, petro-chemical and other uses. The all-India surplus expected each year during the Third Five-Year Plan is shown in the table VI. In this connection, the following points may be borne in mind :—

- (a) The production of motor gasoline from Gauhati has been indicated by IRL to be 160,000 metric tons per annum. We have, however, added another 10,000 tons per annum, which is a part of the light aromex (36,000 tons per annum) which might have to be blended with motor gasoline.
- (b) According to the Project Report received from Russia, the production of motor gasoline from Barauni when all the phases of construction are complete would be 350,000 tons per annum. On account of the manufacture of lubrication oils instead of Jute Batching Oil there is likely to be an increase of 5,000 tons per annum of motor gasoline. In the Barauni production pattern is included 120,000 tons per annum of J.P.4. No decision has been taken so far regarding the utilisation of this product; 54,000 tons per annum which is the motor gasoline component of J.P.4 has, therefore, been included in the motor gasoline from Barauni.
- (c) Export: There has been an export of about 200,000 tons of motor gasoline during 1960. It is reported that exports may dwindle in the next few years. At the same time the surplus of naphtha may be at the peak figure because of time-lag involved in its off-take. Special efforts may, therefore, be necessary to find outlets for peak surpluses during these years.
- (d) Efforts have all along been made during the Second Five-Year Plan to reduce the production of motor gasoline in the private sector refineries. There is a proposal for the industry to revise the specifications of products like kerosene, H.S.D. and furnace oil in order to increase the production of middle distillates and decrease that of motor gasoline at the same time. If this is done, the expected inclusion of naphtha in the middle distillates would be:

[illegible]

The surpluses of naphtha indicated in Table VI would decrease correspondingly in each year.

- (e) The production figures of the private sector refineries given in Table VI do not take into consideration any refinery expansion during the Third Plan. It is assumed also that 1960 production of motor gasoline will be maintained. The figures will change to the extent there is a change in the percentage yield of motor gasoline or there is increase in refinery throughput.
- (f) The production from the refinery in South India, which it is understood is being urged for installation in the Third Plan, has been not included in these data.

Regional availability of naphtha

For this purpose four broad refinery supply area can be considered :

- (i) Digboi/Gauhati/Barauni.
- (ii) Vizag.
- (iii) Gujrat.
- (iv) Bombay.

Although production of naphtha in these areas during the Third Plan period is known with fair degree of certainty, its consumption as motor gasoline cannot be easily indicated because the areas have not yet been delimited. Any presently conceived natural supply area based on rail movement will change substantially when products pipelines are commissioned. Since planning of a petro-chemical unit would require an assured supply, involving minimum movement on a long-term basis, factors affecting such availability will govern the choice of allocation for such a unit.

In an Inter-Ministerial meeting held in the Ministry of Commerce & Industry on 8th September, 1961 it was considered that a region-wise assessment may not be realistic at this stage. It was, however, agreed to proceed on the basis that naphtha will be available either from indigenous sources or, if necessary, for a very brief period by imports to feed the approved schemes as also such others as may be considered important enough for a licence under the industries Act on import saving or foreign exchange earning considerations.

TABLE VI
Availability of Raw Naphtha

		(In million metric tons per annum)				
Production		1960 Refining capacity (1960)	1961	1962	1963	1964
		(actual)				
<i>Public Sector Refineries</i>						
Gauhati	..	0.75	—	0.170	0.170	0.170
Barauni	..	2.00	—	—	0.410	0.410
Gujarat	..	2.00*	—	—	—	0.500
						Provi- sional.
		4.75	—	0.170	0.460	0.580
						1.080
<i>Private Sector Refineries</i>						
B.S.R. (Arabian & Safaniyan)	..	2.84	0.425			
S.V.O.C. (Arabian & Safaniyan)	..	1.95	0.361			
Coril (Iranian & Mines)	..	0.88	0.165			
AOC (NHK and Digboi)	..	0.45	0.088			
		6.12	1.039	1.039	1.039	1.039
			1.039	1.209	1.490	2.119
Grand Total	..					
<i>Consumption (all-India) as Motor Gasoline</i>						
..	..	0.830	0.887	0.939	0.996	1.141
						1.220
Surplus	..	0.209	0.152	0.270	0.503	0.973
Export	..	0.204	?	?	?	?

Aromatic Hydro-carbons

There are three possible sources of aromatic hydro-carbons in the present status of the petroleum and petro-chemical industries :

- (1) Straight-run aromatic hydro-carbons contained in an aromatic-rich gasoline, e.g., that obtained from NHK crude;
- (2) Aromatic hydro-carbons contained in catalytically reformed gasolines;
- (3) By-product aromatics contained in liquids from steam-cracking of naphtha.

It is possible to convert toluene or xylene into benzene by hydro-dealkylation. By this process certain catalytic cycle stocks or reformates can also be converted to naphthalene.

Straight-run-Aromatics

Aromatic hydro-carbons can be removed from straight-run gasolines by extraction with ethylene glycols (so-called UDEX process).

The separation of benzene alone by extraction from NHK and ANK straight-run gasoline may, however, not be economically feasible because of the relatively small volumes involved. Separation of total aromatics may be possible but whether to proceed with such recovery must be determined after a study of all factors including its effect on the octane value of the resultant gasoline.

The hydro-carbon group composition of the NHK and Ankleshwar straight-run gasolines is given below :

TABLE VII

Boiling range °C	Yield % wt. on crude	Density P20	Content of Hydro-carbons %		
			Aromatic	Naphthenic	Para- finic
28—60	3.1	0.6640	0	22	78
60—95	5.4	0.7350	12	54	34
95—122	4.7	0.7702	25	48	27
122—150	4.9	0.7950	43	31	26
150—200	9.7	0.8208	57	25	18
28—200	27.8	0.7700	34	35	31

Sources : Russian Project Report.

The actual yields of BTX based on one million metric tons of crude would be :

For NHK Crude (based on individual hydro-carbon content of gasoline)

From Table VIII:

Benzene	.. .	7,800 tons
Toluene	.. .	10,400 "
Xylenes	.. .	22,700 "

TABLE VIII

*Hydro-carbons (of b.p. below 160°) in Nahorkatiya Gasoline
Expressed on Vol. % of total distillate from 40° to 180°C*

(*This distillate fraction is about 27% by volume of the crude oil)

Hydro-carbon										Approx. Vol. %
<i>Paraffins</i>										
Dimethyl butanes	}	--	--	--	--	--	--	--	3.8	
Methyl Pentanes										
N-hexane	.. ..	..	..	..	..	..	..	..	8.8	
Dimethyl pentanes										
Methyl hexanes	.. ..	..	..	..	..	..	..	..	6.7	
N-heptane	.. ..	..	..	..	..	..	..	..	6.2	
Dimethyl hexanes	.. ..	..	..	..	..	..	..	..	4.6	
Methyl heptanes	.. ..	..	..	..	..	..	..	..	0.5	
N-Octane	.. ..	..	..	..	..	..	..	..	2.7	
Dimethyl heptanes	.. ..	..	..	..	..	..	..	..	4.5	
N-Octane	.. ..	..	..	..	..	..	..	..	2.7	
Dimethyl heptanes	.. ..	..	..	..	..	..	..	..	4.5	
Methyl Octanes	.. ..	..	..	..	..	..	..	..	2.4	
N-nonane	.. ..	..	..	..	..	..	..	--	1.2	
Dimethyl Octanes	.. ..	..	..	..	..	..	..	..	1.6	
<i>Naphthenes</i>										
Cyclopentane	.. ..	..	--	--	--	--	--	--	0.0	
Methyl Cyclopentane	.. ..	..	..	..	..	..	..	..	0.3	
Cyclohexane	.. ..	..	..	..	..	..	..	..	3.1	
Dimethyl Cyclopentanes	.. ..	..	..	..	..	..	..	..	1.4	
Methyl Cyclohexane	.. ..	..	..	..	..	..	..	..	3.6	
Alkyl Cyclopentanes (c8)	}									
Alkyl Cyclohexanes (c8)		..	..	..	..	..	..	..	7.1	
Alkyl Cyclopentane s (c9)	}									
Alkyl Cyclohexanes (c9)		..	..	..	..	..	..	..	7.0	
<i>Aromatics</i>										
Benzene	.. ..	..	..	..	..	..	..	..	2.9	
Toluene	.. ..	..	..	..	..	..	..	..	4.0	
Ethyl Benzene	.. ..	..	..	..	..	..	..	..	0.4	
p-xylene	}									
m-xylene		..	..	..	..	..	..	..	6.1	
O-Xylene	.. ..	..	..	..	..	..	..	..	3.2	
Isopropyl benzene	.. ..	..	..	..	..	..	..	..	1.6	
N-propyl benzene	.. ..	..	..	..	..	..	..	..	1.6	

Source : C.F.R.I. Analysis : Evaluation of NHK crudes part IV (Structure and composition of the gasoline).

TABLE IX

Hydro-carbon Type Analysis of Ankleshwar Crude Gasoline

Fraction No.	Boiling Range °C	Position on crude Vol. %	*Yield on total gasoline cut Vol. %	Composition per cent volume				
				Aro- matic	Ole- fines	Satur- ates (R+N)	Para- ffins	Naph- thene
1	31—55	3.0—5.5	5.55	0.0	0.0	100.0	98.3	1.7
2	55—68	5.5—8.0	5.55	0.0	0.0	100.0	94.0	6.0
3	68—79	8.0—10.5	5.55	2.7	0.0	97.3	46.3	51.0
4	79—88	10.5—13.0	5.55	3.4	0.0	96.6	45.2	41.4
5	88—95	13.0—15.5	5.55	6.2	0.0	93.8	44.4	49.4
6	95—103	15.5—18.0	5.55	7.8	0.0	92.2	46.5	45.7
7	103—107	18.0—20.0	5.55	9.6	0.0	90.4	41.0	49.4
8	107—114	20.5—23.0	5.55	11.0	0.0	89.0	41.8	47.2
9	114—122	23.0—25.5	5.55	11.8	0.0	38.2	54.9	33.3
10	122—128	25.5—28.0	5.55	18.4	0.9	85.7	53.4	32.3
11	128—136	28.0—30.5	5.55	17.0	1.1	81.9	56.0	25.9
12	136—145	30.5—33.0	5.55	18.1	1.6	80.3	50.9	29.4
13	145—154	33.0—35.5	5.55	16.3	1.3	82.4	51.6	30.8

Sources : C.F.R.I. Report on Ankleshwar crude No. 1, Part II—Composition of the crude.

* Represents 45% by volume of crude Oil.

For ANK crude (approx. figures) (from Table IX).

Benzene	..	..	..	..	3,000 tons.
Toluene	..	..	..	..	9,600 tons.
Xylenes	..	..	..	..	10,800 tons.

Aromatics in reformates

Naphthenic hydro-carbons contained in a straight-run gasoline are converted into the corresponding aromatics when this gasoline is processed by catalytic reforming.

Catalytic reformates from Middle East crudes contain not more than a few per cent of benzene and usually less than one per cent, because the boiling range of the reformer feed-stock normally excludes most of the six carbon atom naphthenes. Such is the case with the Burma Shell platforming unit in Bombay. The initial b.p. of the Iranian virgin naphtha feed to the unit is about 90 to 100 °C. Production of benzene from such units would be small unless C₆ fraction is included in the through-put. With units suitably designed for this purpose the approximate yields of individual aromatic hydro-carbons from Nahorkatiya crudes obtained from cat reformate by UDEX extractions is as follows (based on one million MT of crude). These yields have been calculated from Table IX which gives the percentage of individual aromatic and naphthenic hydro-carbons contained in the gasoline. As no such individual hydro-carbon analysis is available for Ankleshwar crude oil, predicting the yield of aromatic hydro-carbons after reforming has not been attempted. It is felt, however, that the quantity of BTX obtained

after reforming would be of the same order as in the case of Nahorkatiya crude :

NHK Crude	Benzene	..	15,500 MT
	Toluene	..	23,500
	Xylenes	..	43,000

The by-product naphtha from this operation is virtually aromatic free, and finds a ready use in jet fuel, as a raw material for ethylene production by steam-cracking or for the production of synthesis gas.

By-product Benzene

The liquid by-product from ethylene manufacture by steam-cracking of naphtha contains some benzene; depending on the severity of cracking, the yield will vary from about 5% for low severity to about 7% for high severity. Lower the severity, greater is the yield of C5 plus liquids but the lower is the concentration of benzene; hence the recovery of benzene from low severity cracking is considered uneconomic.

For instance, a unit with a throughput of 200,000 metric tons per annum of naphtha will yield about 14,000 tons benzene as a result of high severity cracking, as against about 10,000 tons by low severity cracking. The concentration of benzene on the UDEX charge may be of the order of 40% in the former cases as against about 15% in the latter.

Naphthalene

For the production of naphthalene by hydrodealkylation a very large cat cracker to provide cycle oil is usually necessary—much larger than anything present alone or in combination in India. Cuts of cat reformates used in the USA as raw materials for naphthalene are of a type that will not be available in India because the necessary fractions are invariably included in the kerosene fractions in all the Indian refineries. The aromatic extract obtained as a result of sulphur dioxide treatment of Nahorkatiya kerosene fractions may be of interest as source material for naphthalene.

Petroleum Coke

Petroleum coke is mainly required for the aluminium, calcium carbide, ferro-alloys and graphite industries. At present the AOC's refinery at Digboi (capacity 0.45 million tons) produces about 11,000 tons per annum of green coke in a Dubbs Thermal Cracking unit. Typical analysis of Digboi coke is given below :—

Moisture	5-12% by wt.
Volatile matter	10-12% ..
Fixed carbon	90%
Ash	0.2 to 0.45% by wt.
Total Sulphur	0.4% by wt. maximum
Calorific value	15,590 by BTU/lb.

Gauhati refinery (0.75 million tons) will be producing 39,000 tons per annum and Barauni Refinery (2 million tons) about 75,000 tons

per annum of green coke by 1962 and 1963-64 respectively. The quality of coke will be similar to the Digboi coke.

Wax

At present only the A.O.C's refinery at Digboi produces paraffin wax. In 1960, out of a production of 33,000 tons about 20,000 tons were exported, the rest being consumed in the country. The internal consumption is expected to increase to about 25,000 tons per annum by 1966. The chances of exporting increasing quantities of wax are not bright, hence if not used as chemical feed-stock almost all the wax extract or slack wax produced at the Barauni refinery (about 80,000 tons per annum) and other proposed lubricating oil plants may have to be cracked, coked or burnt as fuel. Some possibilities of using wax are indicated below :

Thermal cracking of waxy material in the vapour phase produces higher molecular weight olefines which are valuable chemical feed-stocks. They are used for the production of higher alcohols, detergents like alkyl sulphates, and lubricating oil additives.

Chlorinated paraffin waxes are used as extreme pressure lubricant bases, flame proofing agents and plasticisers. Paraffin, an important pour point depressant is a condensation product of chlorinated paraffin wax and naphthalene. Oxidation of paraffin wax has been used for making solvents, plasticisers, soaps, lacquers etc.

Feed-stocks for Carbon Blacks

Channel Black and reinforcing type Furnace Black can be manufactured from natural gas. Refinery aromatic rich liquid streams like lubricating oil extracts, kerosene extracts called aromex, cat-cracked slurries or bottoms, etc. can be used for the production of furnace blacks.

Availability of natural gas has already been discussed.

Lubricating oil extracts obtained as a result of phenol or furfural treatment of lube distillates will be produced in the Barauni refinery and other proposed lubricating oil plants. The phenol extract from Barauni (about 57,000 tons per year) will be mostly used as a blending stock for the manufacture of blow bitumen. The extracts from the other proposed lube plants would however, be available for Carbon Black manufacture.

Sulphur-dioxide extract of kerosene will be available from the public sector refineries at Gauhati and Barauni. The refinery at Gauhati will produce 36,000 tons per annum of light aromex (boiling range 152—232° C) and 28,000 tons per annum of heavy aromex (boiling range 230—270° C). All the heavy aromex has been earmarked for inclusion in the fuel oil. Whether any portions of heavy aromex can be made available and used for the manufacture of Carbon Black remains to be investigated. Whether any portion of light aromex would be suitable for manufacture of Carbon Black also needs investigation. Similarly, Barauni refinery will produce 130,000 tons per annum of aromex having a boiling range of 180—270° C. This aromex could be further concentrated

to obtain a heavier fraction, if necessary, having a specific gravity of 0.95 to 1.0, (17.5 to 10 A.P.I. gravity), characterization factor of less than 10, and aromatic content of 80 to 90%. This fraction is likely to have a Bureau of Mines Correlation Index (B.M.C.I.) of the order of 100 and molecular weight of about 150. The aromex from Gauhati will become available in early 1962 and it should be possible to conduct experiments on actual samples.

All cracked stock available from the existing refineries has a low value of B.M.C.I. (about 60—70) and thus is unsuitable for carbon black manufacture.

Ethylene tar from a steam-cracker is a possible raw material for the manufacture of Carbon Black.

Statements giving detailed information in respect of :

- (1) Refinery production statistics;
- (2) Estimated consumption of petroleum products during the Third Plan; and
- (3) Estimated surplus or deficit in the main petroleum products in 1966, based on 10.87 million tons refining capacity; have been prepared.

It would be seen from Statement (3) that by the end of the Third Plan period, except in the case of motor gasoline, there is a deficit in all the other items, particularly the middle distillates. Additional refining capacity would not only help in reducing/removing these deficits but would also yield additional naphtha for the Petro-chemical Industry.



सत्यमेव जयते

Refinery Production Statistics

(Figures in Metric Tons)

Product	Actual figures for 1960					Design Figures			Provisional*	Total
	A.O.C.	B.S.R.	S.V.R.C.	CORIL		Gauhati	Barauni	Gujarat		
Aviation Gasoline	88,016	375,867	361,221	165,218	10,000	160,200	354,500	500,000	2,005,022	10,000
Motor Gasoline	—	48,751	—	—	—	—	—	—	48,751	—
Motor Gasoline 80 ON	—	—	—	—	—	—	—	—	—	—
A.T.F. (Kerosene type)	73	—	—	—	—	—	—	—	68,573	—
J.P. 4 (Wide cut-gasoline)	—	—	—	—	—	—	—	—	120,000	—
Kerosene Superior	43,684	529,017	213,403	100,031	104,000	104,000	155,000	480,000	1,625,135	—
Kerosene Inferior	36,782	—	3,804	4,471	59,700	59,700	47,100	—	151,857	—
High Speed Diesel Oil	37,139	601,345	271,860	170,415	119,000	119,000	376,000	500,000	2,075,757	—
Light Diesel Oil	44,938	154,585	224,103	96,211	64,500	64,500	164,600	—	747,942	—
Furnace Oil	61,861	685,175	356,532	248,838	113,200**	113,200**	220,000	—	—	—
Low sulphur Fuel Oil	—	—	231,486	60,861	—	—	—	420,000	2,397,953	—
H.H. Stock	—	268,452	119,847	—	—	—	105,000	—	504,777	—
Bitumen	11,478	5,797	2,246	—	—	5,000†	20,000	—	33,043	—
L.P. Gas	—	—	—	—	—	39,000	72,500	—	124,023	—
Petroleum Coke	1,828	—	—	—	—	—	—	—	1,828	—
Sleeper Oil	6,595	—	—	—	—	—	—	—	6,595	—
Mineral Turpentine	21,255	—	—	—	—	—	46,000	—	67,255	—
Lubricating Oil***	342	—	—	—	—	—	—	—	342	—
Technical White Oil	7,999	2,520	37,476	38	—	—	—	—	48,033	—
J.B. Oil	2,250	—	—	—	—	36,000	—	—	38,250	—
Aromex	3,516	—	—	—	—	—	—	—	3,516	—
Vap. Oil	1,016	—	—	—	—	—	—	—	1,016	—
Wash Oil	33,238	—	—	—	—	—	—	—	33,238	—
Wax	4,087	—	—	—	—	—	—	—	4,087	—
S.B.P. Spirits	948	—	—	—	—	—	—	—	948	—
Others††	—	—	—	—	—	—	—	—	—	—
TOTAL	419,568	2,671,509	1,821,983	845,081	700,600	1,759,200	1,900,000	10,117,941	10,117,941	—
CRUDE RUN	449,341	2,943,006	1,948,475	878,491	750,000	2,000,000	2,000,000	10,869,313	10,869,313	—

*Based on Ankleshwar Crude. **Portion of it may be used as Refinery Fuel. †Planned.

***Two more lubricating oil plants which may produce about 100,000 tons of basic oils each, are being planned to be installed during the Third Plan.

†† Include Wood Oil, Malorial, Solar Oil, Mineral Jolly and earth oil.

*Estimates of Consumption of Petroleum Products
During the 3rd Plan†*

(in 1000 metric tons)

Products	Actual						
	1960	1961	1962	1963	1964	1965	1966
1. Aviation Gasoline	87	70	66	62	58	54	51
2. A.T.F. including JP4 & JP5	179	228	285	342	377	415	457
3. Motor Spirit including PA/Benzol	854	887	939	996	1,066	1,141	1,220
4. Illuminating Kerosene	1,972	2,069	2,204	2,355	2,523	2,703	2,896
5. Power Kerosene	26	20	17	14	12	10	8
6. High Speed Diesel Oil	1,227	1,415	1,647	1,930	2,258	2,647	3,049
7. I.D.O./M.D.O.	652**	651	695	743	796	853	915
8. Fuel Oil including L.S.F.O./Pitch	1,745**	1,441	1,600	1,787	2,003	2,256	2,541
9. Jute Batching Oil	84	81	81	81	81	81	81
10. Bitumen	408	425	451	504	568	638	711
11. Lubricants & Greases	243†	291	318	347	380	416	457
12. Other Products*	174***	172	301	385	574	866	1162
	7,651	7,750	8,604	9,546	10,696	12,089	13,548
13. International Bunkers							
(a) H.S.D.		2	2	2	2	2	3
(b) I.D.O.		31	31	32	32	33	33
(c) Fuel Oil		449	469	490	511	533	559
GRAND TOTAL	7,651	8,232	9,106	10,070	11,241	12,657	14,143

*Vide page 39.

**Including bunkers.

*** Gas, intermediate and other products.

† As agreed in the meeting of the Steering Committee of the Oil Advisory Committee held on 9th March, 1961.

‡ Lubricants only.

Demand estimates for Other Products

Other Products	(Figures in 1000 metric tons)						
	1960	1961	1962	1963	1964	1965	1966
S.B.P. Spirit including Hexane	..	33	37	44	53	63	76
Mineral turp ti	..	23	25	28	31	35	38
Wax	..	19	20	22	23	24	25
L.P.G.	..	14	26	41	57	75	96
Lubricating including Malarol	..	17	19	21	24	27	30
Aromex	..	3	38	38	38	38	38
Coke	..	57	89	85	90	95	100
Chemical Shelltox etc.	..	4	4	4	5	5	5
Refinery Gas & Naphtha	..	—	50	100	251	502	752
Misc. Products	..	2	2	2	2	2	2
	59	172	301	385	574	866	1,162



सत्यमेव जयते

*Estimated Surplus or Deficit in Main Petroleum Products in 1966
Based on 10.87 Million Tons Refining Capacity*

(Figures in 1000 metric tons)

Products	Estimated Production in 1966 based on existing refineries 1970 production	Estimated Consumption 1966	Surplus/ Deficit
1. Aviation gasoline	10*	51	— 41
2. Motor Gasoline	2,054	1,220	+ 834
3. ATF including JP 4** & JP 5	189**	457	— 268
4. Kerosene	1,777	2,896	— 1,119
5. High speed Diesel Oil	2,076	3,049	973
6. Light Diesel Oil	748	948@	— 200
7. Fuel Oil including L.S.F.O. and H.H.S.	2,398	3,100@	— 702
8. J.B.O.	48***	81	— 33
9. Bitumen	505	711	— 206
10. Lubricants & Greases	67†	457	— 390
			+ 834
TOTAL	9,872	12,970	— 3,932

* This is 73 Ton. clear aviation gasoline. The demand for this product may not reach 10,000 tons per annum by 1966. The deficit in other grades of aviation gasoline will increase correspondingly.

** No decision has yet been taken regarding the utilisation of JP 4 in India. Production figures include 120,000 tons per annum of JP 4.

@ Includes bunkers, Consumption of furnace oil may considerably increase the given figure.

*** Sufficient JBO manufacturing capacity exists to meet the consumption.

† Does not include greases. Two Lubricating oil plants are under consideration.

11. Petroleum coke	124	—	—
12. Wax	33	25	+ 8

CHAPTER IV

ORGANIC CHEMICALS AND OTHER PRODUCTS TO BE MANUFACTURED FROM PETROLEUM PRODUCTS

Introduction

During the last few years in many advanced countries of the world products such as synthetic rubber, plastics, pesticides, detergents and organic solvents are being manufactured as petro-chemicals, i.e., as chemical materials which are wholly or partially derived from petroleum or natural gas. Till recently, the industrial backwardness of the country, particularly in the Organic Chemicals field, and the non-availability of oil and/or gas had stood in the way of the development of petro-chemicals industry in the country. With the discovery of oil and gas in Assam and Gujarat and the decision to set up one more refinery bring the refining capacity in the country by the end of the Third Plan period to at least 10.8 million tons per year, and to 18-20 million tons by 1970-71, it is likely that adequate quantities of petroleum fractions and gas would become available for the manufacture of petro-chemicals, the demand for which is rising rapidly. Petroleum is no longer merely a specialised fuel which is burnt for its energy. It is a mixture of aliphatic, naphthenic and aromatic hydro-carbons and the hydro-carbons themselves concentrated and purified are petro-chemicals, e.g., ethane, propane, butane, iso-butylene, pentanes, N-Hexane, cyclo-hexane, benzene and toluene. In addition to these, a large variety of petro-chemicals are produced by one or more reactions based on the petroleum product.

2. Today, in advanced countries a large number of chemical substances are made by two methods, a standard and by now conventional method and by a newer method using petroleum products as a starting material. For example, phthalic-anhydride was made from naphthalene, a coal-tar product, in the older method, but in the newer process it is made from o-xylene, a petro-chemical. Acetone, made by dehydrogenation of iso-propyl alcohol, itself made by hydration of propylene produced in the refinery, accounted for nearly 96% of the total production of acetone in U.S.A. in 1951 and has made obsolescent the older method of making it by the fermentation process. According to a recent process, acetone can also be produced by the splitting of cumene (produced from benzene and propylene) into phenol and acetone. Even ethyl-alcohol, one of the oldest organic chemicals, is being made in substantial quantities from ethylene, a petro-chemical, in competition with the fermentation product.

3. The three main sources of synthetic organic chemicals in the world today are coal, vegetable products and oil. Petroleum products happen to be the newest of the three principal key materials and these have certain advantages. Just as the setting up of the coke-ovens has provided the starting materials like benzene, toluene, xylenes, naphthalene, phenol and anthracene, for the manufacture

of organic chemicals in the country, the discovery of oil and gas and the setting up of refineries provide the starting materials for the Petro-chemicals Industry in the country. While the raw materials from carbonisation of coal are aromatic compounds, those from petroleum are largely aliphatic compounds. Since modern processes enable compounds of both types to be obtained from either coal and petroleum may be regarded as complementary as well as supplementary sources of chemicals. Both are, therefore, necessary for the modern Organic Chemicals Industry.

4. The Petro-chemicals Industry is only about 40 years old; for well-known reasons it was developed originally in America. Practically, there was no Petro-chemical Industry in the U.K. till the outbreak of the World War II. The removal of duty on imported hydrocarbon oils used for chemical synthesis, as recommended by the Ayre Committee (1944) together with the world changes in the sources of supply of cheap oil laid the foundation for a flourishing Petro-chemicals Industry in that country. Wider dispersal of refining capacity which has taken place in the post-War period provided the facilities in many other countries as well, e.g., Japan.

5. In India, at present there is no Petro-chemical Industry of significance. However, a beginning has been made in this direction with the recent decision to:

- (i) licence the setting up of two steam-cracking units in the Bombay region for providing the starting material needed for the manufacture of organic chemicals and other products;
- (ii) utilize the associated gases at Nahorkatiya for the manufacture of nitrogenous fertilisers, Cis-4-Polybutadiene (a new type of synthetic rubber), polyethylene and Furnace type Carbon Black;
- (iii) issue a licence for the manufacture of phenol and acetone by the cumene process (cumene itself would be manufactured from benzene and propylene in the next phase); and
- (iv) approve a number of schemes for the manufacture of nitrogenous fertilisers based on naphtha.

6. Apart from the above, several schemes for the manufacture of phthalic anhydride, PVC, polyethylene, polystyrene, etc., have been approved/licensed and many of these schemes may have to depend on petroleum products for their primary starting materials.

7. Till recently, very little was known in India about the scale on which production of petro-chemicals should be organised. It is necessary to ascertain how a beginning should be made in this field on the right lines. This calls for studies which involve:

- (a) drawing up a list of petro-chemical products for undertaking their manufacture during the next ten years in the country and to determine the capacity in respect of each important product having regard to relevant factors such as optimum economic size, estimated domestic demand,

export potentialities, availability of the same chemical/product from other sources (such as coal-tar/coke oven gas molasses-based products), trends in consumption pattern (e.g., Natural Rubber being supplemented/replaced by synthetic rubber, soap being supplemented/replaced by synthetic detergents); and

- (b) determining the facilities to be set up for making available on a sustained basis and at economic prices adequate quantities of primary or fundamental "building blocks" such as :

- (i) Olefines (ethylene, propylene, butylenes and butadiene);
- (ii) Aromatics (benzene, toluene, xylenes etc.);
- (iii) Acetylene;
- (iv) Paraffins (methane, ethane, propane, butanes and pentanes)

for further conversion and manufacture of petro-chemical products indicated at (a) above; and

- (c) pattern of integrated production of organic chemicals from techno-economic consideration.

What petro-chemicals and other products to manufacture and in what quantity

8. This Section deals with part (a) of the question raised in the previous paragraph. Part (b) of the question would be dealt with in a separate Chapter. There are over three thousand different chemicals derived from petroleum. Of these about 300 could be classified as "important commercial chemicals" and only about fifty are large volume items.

9. In the U.S.A. and in the industrially advanced countries of Western Europe the demand forecasts for different organic chemicals and other products are worked out on the basis of projecting the consumption growth rates in relation to current levels and the growth of incomes and their distribution in the community. The studies would also cover patterns and shifts in consumption expenditure. Such an approach is not feasible at the present stage in India, because the Organic Chemical Industry is still in the infancy. Further in a planned economy dependent on heavy imports for development, restraints on consumption are expected to operate. The Committee is not in a position to make assumptions about such restraints. By the end of the Fourth Plan period one might anticipate that the country would have reached a stage which would enable demand forecasts being worked out as in industrially advanced countries. The restrictive factors acting as a brake on consumption will also have been largely overcome by the end of the Third Plan and production could be expected to expand freely in response to demand.

Tentative Targets

10. At present, the targets for the diverse organic chemicals and other products needed in the country under the Third and the Fourth

Five-Year Plans will have to be worked out on a somewhat different basis. It would first of all be necessary to work out the estimates regarding domestic demands against the background of relevant factors. It would also be necessary to take into account the minimum optimum economic sizes and export potentialities in order to fix realistic targets for the production of organic chemicals and other products based on them. Some of the more important products, the production of which will have to be taken up first, are given below together with their tentative targets for the Third and the Fourth Plans (A further list is at Appendix VI).

(Value in Rs. lakhs)						
Name of the material	Unit	Estimated Demand				
		1965-66		1970-71		
		Quantity	Value	Quantity	Value	
1. Nitrogenous Fertilizers (in terms of nitrogen) ..	'000 tons	1,000	—	2,000		
<i>Organic Chemicals</i>						
2. Methyl alcohol	Tons	25,000	100	60,000	280	
3. Ethyl Alcohol	"	200,000	600	290,000	870	
4. Acetone	"	9,500	95	18,000	180	
5. Acetic Acid	"	29,000	348	57,000	684	
6. Phenol	"	18,000	400	43,000	945	
7. Dodecyl benzene	"	8,000	160	24,000	480	
8. Ethylene Oxide	"	5,000	150	10,000	300	
9. Carbon tetra-chloride and chloro-methane	"	8,000	140	10,000	250	
10. Aniline	"	4,000	120	10,000	300	
11. Benzene	"	80,000	480	170,000	1,020	
12. Naphthalene	"	20,000	120	40,000	240	
13. Phthalic Anhydride	"	13,000	390	28,500	850	
<i>Pesticides</i>						
14. D.D.T.	"	6,000	240	9,000	360	
15. B.H.C.	"	15,000	345	24,000	625	
<i>Plastics</i>						
16. P.V.C.	"	30,000	960	75,000	2,490	
17. Polyethylene						
(a) Low density	"	28,000	1,260	100,000	4,000	
(b) High density	"	8,000		15,000		
18. Polystyrene	"	20,000	600	50,000	1,500	
19. Polypropylene	"	4,000	300	20,000	10,000	
<i>Synthetic Elastomers</i>						
20. S.B.R.	"	30,000	2,310	30,000	5,610	
21. Cis-4-Polybutadiene	"	30,000		80,000		
22. Poly-isoprene	"	—		30,000		
23. Butyl Rubber	"	10,000		30,000		
<i>Others</i>						
24. Carbon Black	"	35,000	350	70,000	700	
25. Nylon	"	2,000	560	8,000	2,240	

11. A delegation on behalf of the Organic Chemicals Panel of the Development Council for Organic Chemical Industries discussed with the Petro-chemicals Committee the desirable targets for a number of heavy organic chemicals during the Third and the Fourth

Plan periods. The Committee was generally in agreement with the suggestions made by the Organic Chemicals Panel. The Committee is of the view that if there are no restraints on consumption and investments nor abnormal price increases, the demand estimates given above would definitely be reached. It has also been noted that the targets proposed in the Report on the Third Plan for some of these products for 1965-66 are lower than those suggested by the Development Council. The Report, however, states that the revision of these targets is open to consideration in the Third Plan period.

Estimated requirements of Primary Raw Materials

12. For the targets for plastics, pesticides etc., the Committee has drawn largely on the deliberations of the Development Council for Organic Chemical Industries. A seminar on "Petro-chemicals Industry" held in Delhi in May, 1961, under the auspices of the Northern Regional Centre of the Indian Institute of Chemical Engineers was also helpful in this connection. The estimated requirements of the primary raw materials for the organic chemicals and other products listed on the previous page would broadly be as follows :

	1965-66	1970-71
	tons	tons
1. Methanol	25,000	60,000
2. Ethyl Alcohol	200,000	290,000
3. Ethylene	50,000	165,000
4. Propylene	20,000	70,000
5. N-Butane/N-Butylenes	60,000	160,000
	45,000	120,000
6. Isobutylene	13,000	67,500
7. Acetylene	24,000	59,000
8. Benzene	80,000	170,000
9. Naphthalene	20,000	40,000

13. Production of methanol and ethylene could be organised either from coke-oven gases or petroleum feed-stocks; propylene, N-butane/N-butylenes, Iso-butane/Iso-butylenes would have to be based on petroleum feed-stocks.

14. The entire requirement of ethyl-alcohol would be obtained by the fermentation of molasses and it would not be necessary to produce ethyl-alcohol based on petroleum products.

15. It is estimated that benzene to the extent of 50,000 tons by the end of the Third plan and about 100,000 tons by the end of the Fourth Plan would be available from coal-tar sources. It would, therefore, be necessary to plan for the production of benzene to the extent of 30,000 tons during the Third Plan and 80,000 tons during the Fourth Plan from petroleum sources.

16. Naphthalene to the extent of about 12,500 tons by the end of the Third Plan and 25,000 tons by the end of the Fourth Plan is expected to become available from coal-tar sources. Production of naphthalene from petroleum sources is unlikely because suitable raw materials are not readily available in the country. Therefore, the

only alternative would be to use O-xylene in place of naphthalene, wherever necessary, for the production of phthalic-anhydride.

N.B.—The estimated availability of benzene and naphthalene has been worked out on the basis of the targets fixed for steel production during the Third and the Fourth Plan.

17. The entire quantity of acetylene needed by the end of the Third Plan is assumed to be met from calcium carbide, the targetted capacity for which is adequate to meet this demand. During the Fourth Plan there might be some production of acetylene from petroleum sources depending upon its economics.

18. The demand for Cis-4-polybutadiene, polyisoprene and butyl rubbers are likely to be interchangeable and this fact would have to be taken into consideration while creating capacity for manufacture of synthetic rubbers. The position would be somewhat similar in the case of major plastics, viz. PVC, polyethylene and polystyrene.

19. As already indicated the targets for the more important products listed at para 10 have been suggested taking into consideration estimated domestic demand, optimum economic size, export potentialities, etc. It might be useful to briefly indicate how these targets have been worked out in respect of certain more important items.

Nitrogenous Fertilizers

20. As is well-known the production of nitrogenous fertilizers could be based on the utilization of naphtha (surplus motor-spirit). Recently, naphtha, refinery gases, natural gas (associated gas) and gases from naphtha crackers and coke-oven gas have been considered as a source of synthesis gas for the production of nitrogenous fertilizers in the country. As indicated in the Draft Outline of the Third Five-Year Plan, the production capacity of nitrogenous fertilizers in terms of nitrogen is to be raised from about 234,000 tons in 1960-61 to 1,000,000 tons by 1965-66. According to the present indications, out of the additional production of fertilizers needed to reach the target fixed for the Third Plan, fertilizers corresponding to about 400,000 tons of nitrogen would be based on petroleum products. The production of the balance quantity of nitrogenous fertilizers would be based on coke, lignite, gasification of coal, coke-oven gases and electrolytic hydrogen.

21. The proposals received recently by the Ministry of Commerce & Industry for setting up a fertilizer factory in the private sector at Vizag have highlighted the preference of the private sector for organising such production from naphtha or refinery gases. The main reason for such a preference is the fact that the investment per ton of ammonia is about 30% less for a naphtha based unit in comparison with that based on coal. Out of the estimated availability of surplus naphtha nearly 50% would be needed for the production of nitrogenous fertilizers during the Third Plan period.

21(a) The production of sufficient food is undoubtedly going to be one of our biggest problems during the next ten years. The use of nitrogenous fertilizers would be vital for increasing our food production. The ratio of nitrogen consumption per thousand of

population would increase a little over four-times from 0.49 to 2.08 during the Third Plan period. The following table sets out the estimation of population growth, prepared by the Central Statistical Organisation, which has been accepted as a working basis for the preparation of the Third Plan along with the nitrogen consumption and the ratio of nitrogen consumption per thousand of population :

TABLE I

	Unit	1951	1956	1961	1966	1971
Estimated population	Millions	362	396	431	480	528
Consumption of nitrogenous fertilizers: (in terms of nitrogen)	'000 tons	9	79	210	1,000	1,500
Ratio of nitrogen consumption (per 1000 of population)	Tons/1000 population			0.49	2.08	2.84

22. It is anticipated that when we consume a million tons of nitrogenous fertilizers by the end of the Third Plan, the country would have reached a stage which would enable further studies to be based on the growth of nitrogen consumption in relation to population. It might be seen from the table given below that the ratio of nitrogen consumption per thousand of population in the world has increased by 50% during the course of five years. During the next five years it is apparent that the consumption rate will grow at a faster rate. It is on this basis that the targets of 2.0-2.2 million tons of nitrogenous fertilizers has been suggested for India for 1970-71.

TABLE II

Growth of nitrogen consumption in relation to world population

Year ending June 30		1953	1954	1955	1956	1957	1958	1959
Estimated world population*	Million	2,460	2,480	2,510	2,550	2,590	2,633	2,684
World nitrogen consumption for fertilizers ..	Thousand metric tons	4,968	5,384	5,925	6,305	6,999	7,831	8,212
Ratio of nitrogen consumption per 1000 of population	Metric tons/ 1000 population	2.12	2.17	2.36	2.47	2.70	2.97	3.06

* Excludes U.S.S.R.

(Reproduced from "THE FUTURE OF CHEMICALS FROM PETROLEUM" by L. H. Williams—Chemistry & Industry, August 6, 1960—page 1014).

Methyl Alcohol

23. Although the present imports of methanol and methanol-based derivatives (in terms of methanol) are of the order of 3,000 tons per year, the demand for it is likely to increase steeply during the Third Plan period. Two formaldehyde plants have already been licensed

and would require over 6,000 tons/year of methanol for their licensed capacity. Formaldehyde itself is required in very much larger quantities for the manufacture of phenolic and urea resins and moulding powder, hexamine, penta-erythritol and other chemicals. The Ministry of Defence is also interested in the production of some of these formaldehyde based chemicals. The capacity for the manufacture of formaldehyde has been restricted only on account of the present necessity to import methanol and as soon as methanol becomes available from indigenous sources, the demand for formaldehyde would increase sharply. Methanol is also required as an important basic chemical in the manufacture of acrylic resins, methylene chloride and other chloro-methanes, terylene, etc. It is also an important solvent besides being used in appreciable quantities as an auxiliary in jet and turbine aircraft. The target for Methanol production has been worked out, as per table given below, taking into consideration the quantities of methanol required for the diverse uses referred to above:

(all in tons)				
	1965-66		1970-71	
	Qty. of product	Qty. of methanol required	Qty. of product	Qty. of methanol required
(1)	(2)	(3)	(4)	(5)
1. Formaldehyde (as 37%)				
For Amino-resins	15,000	15,000	39,000	38,000
For Phenolic resins	5,000		12,000	
Penta-erythritol	2,500		7,000	
Hexamine & other chem.	3,000		6,000	
Textile & other non-chemical uses	4,500		12,000	
	30,000	15,000	76,000	38,000
2. Chemicals and Drugs manufacture including Defence	—	3,500	—	7,000
3. Polymethyl Methacrylate	4,000	1,500	8,000	3,000
4. Methylene Chloride and other chloro-methanes	3,000	1,500	6,000	3,000
5. Aircraft fuel	—	1,500	—	2,000
6. Denaturant and solvent	—	2,000	—	6,000
7. Misc. uses including Terylene (in terylene manufacture, methanol will be recovered so that net requirement is small)	—	—	—	—
	25,000		say 60,000*	

*may increase to 90,000 tons or more if formaldehyde is used in the manufacture of isoprene.

In view of the requirements of methanol indicated above, it would be appropriate if capacity for production of about 40,000 tons/year is set up for meeting our needs during the Third Five Year Plan. Methanol is a volatile inflammable liquid and falls within the category of dangerous petroleum with a low flash point. Therefore, from the

safety point of view as well as to ensure a low price at principal consuming centres it is desirable for the present to set up two units, each with a capacity of 60 tons/day near the main consuming centres of Bombay and Calcutta.

24. Methanol is a highly capital intensive product. It is desirable that the capacity of the methanol plant should be of the order of 60 tons per day at least so that its cost of production is comparable with that in other countries. The raw material for methanol is synthesis gas consisting of carbon monoxide and hydrogen. It can be obtained in various ways as for ammonia synthesis. However, since our requirements of methanol are not as large as those for ammonia, for ensuring low cost production it would be an advantage if the synthesis gas is derived from waste gas or from a larger unit for producing synthesis gas for the simultaneous production of methanol and ammonia. The Fertilizer Technical Committee recommended the setting up of such a plant in its report on Madhya Pradesh Fertilizer Project. Coke-oven gas, if available as surplus, would be such a source. Tail gases of refinery operations or of naphtha-cracking units would also provide similar material on which methanol production could be organised. If natural gas is available at a location near enough to principal consuming centres for methanol, then it would also be a suitable source. Correct location of units for methanol, an important basic chemical, is of utmost importance.

25. Practically our entire requirements of methanol are being met by imports at present. The existing capacity is only in respect of by-product methanol from wood distillation with a small production capacity of less than 100 tons/year. Production of chemically pure methanol at this unit is very costly and the product can preferably be absorbed as wood naphtha. It might be recalled here that before 1926 all American commercial methanol (wood alcohol) was recovered as a by-product of the wood-distillation industry. The availability of German synthetic methanol in 1926 brought about a complete change so much so that presently less than 2% of methyl-alcohol production comes from wood distillation in U.S.A.

Ethyl Alcohol

26. The manufacture of Ethyl Alcohol in the country is based on the fermentation of molasses obtained as a by-product in the Sugar Industry. During the War years this industry was developed for use of alcohol as power alcohol in admixture with gasoline to reduce the imports of the later. With the improvement in the supply position of motor spirit in the country and a simultaneous demand for alcohol as a raw material for the manufacture of certain organic chemicals the process of discontinuing the practice of using alcohol for mixing with motor spirit has already started and almost the entire quantity of alcohol produced in the country would soon become available for the Organic Chemicals Industry. A production target of 60 million gallons (about 200,000 tons) of alcohol has been fixed under the Third Plan. This is based on 1.225 million tons of molasses which are expected to become available as a by-product of 3.5 million tons of sugar which would be manufactured by the end of the Third Plan. Almost the entire quantity of alcohol would be needed to meet the

requirements of the schemes for the manufacture of synthetic rubber (SBR), polyethylene, acetic acid and its derivatives, butyl alcohol and octanol, styrene monomer and various chlorinated derivatives including P.V.C. and quite a few of which have already been licensed. With the increasing availability of cheaper ethylene, propylene, butane, butylene, acetylene etc. from petroleum sources it is unlikely that additional requirements of ethylene, butadiene etc. will be based on alcohol. It is likely that some units such as existing polyethylene unit of M/s. A.C.C.I. at Rishra which have based their ethylene production on alcohol (this unit obtains alcohol from distilleries in Bihar and U.P.) would switch over to ethylene from a petroleum cracker, if such a unit is established in West Bengal. The demand for alcohol is, however, expected to increase to 90 million gallons (300,000 tons) by 1970, as the use of alcohol for acetic acid and acetaldehyde based chemicals would continue without any serious threat from alternative raw materials. If the internal demand does not catch up with the production, alcohol could be exported—this step is being taken at present to get over a similar temporary problem—for a limited period. Taking into consideration the quantity of ethyl alcohol required for diverse uses, the estimated demand by the end of the Third and Fourth Plans have been worked out as shown in the table below:—

Usage	(Quantity in tons)			
	1965-66		1970-71	
	Qty. of product	Qty. of Ethyl-Alcohol	Qty. of product	Qty. of Ethyl-Alcohol
(1)	(2)	(3)	(4)	(5)
B. Ethyl Alcohol				
1. Butadiene and styrene for synthetic rubber (SBR type)	30,000	70,000	30,000	70,000
2. Polyethylene	8,500	17,000	8,500	—
3. Styrene for Polystyrene	14,000	10,000	21,000	15,000
4. N-butanol and N-Butyraldehyde for Octanol	11,000	17,000	207,00	2,000
5. Acetic acid for cellulose acetate	17,000	32,000	25,000	57,000
Other acetates	4,000		10,000	
Acetic anhydride for other uses	2,000		4,000	
Vinyl acetate	2,000		6,000	
Chloroacetic acid	1,500		3,000	
Drugs, dyes, textiles and other uses	4,500		9,000	
	32,000		57,000	
6. Chlorinated derivatives including chloral, DDT, Chloroform, Ethyl-chloride, ethylene dichloride and PVC Mainly DDT—6000 tons } Mainly EDC—2400 tons } Mainly PVC—6000 tons }	—	10,000	—	16,000
7. Potable spirits, drugs, liquors, ordinary Den. spirits	—	30,000	—	45,000
8. Other uses in chemicals and processing industries including acetone and others	—	12,000	—	20,000
TOTAL	—	198,000	—	282,000

The entire requirements of alcohol would be met by the Fermentation Industry and there does not appear to be any need in undertaking the manufacture of alcohol as a petro-chemical.

Aromatic Hydro-carbons (Benzene, Toluene, Xylenes and Naphthalene)

27. It is hardly necessary to emphasize the important role aromatic hydro-carbons play in the manufacture of organic chemicals as they happen to be the starting materials for the manufacture of a wide range of organic chemicals, particularly phenol, styrene; dodecyl-benzene, phthalic acid, dyestuff intermediates etc. The traditional source for the aromatic hydro-carbons is coal-tar and since this has been unable to provide for the rapidly increasing needs of the Organic Chemicals Industry, they are being produced in a big way from petroleum sources, particularly in the U.S.A. Till now, the demand for these chemicals in India was very small, but during the next ten years there would be a steep increase in the demand for them due to the rapid growth of the Organic Chemicals Industry in the country. The anticipated demand for these products by 1965-66 and 1970-71 would be as given in the table below :

		1965-66	1970-71
		tons	tons
Benzene	.. .. .	80,000	170,000
Toluene	.. .. .	4,000	6,000
O-xylene	.. .. .	10,000	30,000
P-xylene	.. .. .	1,000	3,000
Naphthalene	.. .. .	20,000	40,000

Benzene

28. In the past the demand for benzene for the Organic Chemicals Industry was small so much so that appreciable quantities of benzene and toluene fractions were diverted to motor benzol. Benzene recovery from coal carbonisation units by the end of the Third Plan is estimated to yield about 50,000 tons of benzene as against an anticipated demand of 80,000 tons by 1965-66, which would rise to about 170,000 tons by 1970-71.

The consumption pattern is indicated in the following table:

BENZENE

Usage	(Figures in tons)			
	1965-66		1970-71	
	Qty. of product	Qty. of Benzene required	Qty. of product	Qt. of Benzene required
1. <i>Styrene</i>				
For polystyrene and co-polymers. ..	20,000	—	50,000	—
Latex resins, foams & high impact resins	3,000	—	9,000	—
S.B. Rubber	8,000	—	8,000	—
Polyesters and Misc.	2,000	—	4,000	—
	33,000	33,000	71,000	71,000

Usage	1965-66		1970-71	
	Qty. of product	Qty. of Benzene required	Qty. of product	Qt. of Benzene required
2. Synthetic Phenol				
For caprolactum (fibres and plastics)	12,000			
phenolic resins	4,000			
Synthetic drugs	1,000			
Alkyl phenol	1,500			
Pesticides	700			
Dyestuffs	300			
Less recovery from coal/Lignite carbonisation	2,000			
	17,500	18,000	43,000*	43,000
3. B.H.C.	15,000	6,000	25,000	10,000
4. D.D.T.	6,000	3,000	9,000	4,000
5. Dodecyl Benzene	8,000	2,500	24,000	7,500
6. Maleic anhydride	2,000	2,500	5,000	6,500
7. Aniline	4,000	4,000	10,000	10,000
8. Mono & Dichloro benzene	2,000	1,500	4,000	3,000
9. Misc. industrial and solvent usage	—	6,000	—	12,000
		76,500		167,000

*assuming a 100% increase in nylon and use of phenol for the increased product.

29. Coal carbonisation is linked mainly to steel production and since the rate of increase in production of organic chemicals would be much faster compared to the rate of increase in steel production, it is obvious that the coal carbonisation units will not be able to meet the increasing demands for benzene. The gap to the extent of about 30,000 tons by the end of the Third Plan period is likely to increase to about 70,000 tons by the end of the Fourth Plan. It is, therefore, necessary to plan the production of benzene from petroleum sources. Some steps have already been taken in this direction and part of the gap during the Third plan period would be filled by the recovery of benzene to the extent of about 10,000 tons from steam-cracking units in the Bombay region, which are to be installed mainly for the production of basic olefins namely ethylene and propylene.

30. Aromatics are generally made from petroleum sources by the catalytic reforming of naphthenic rich fractions. Of the several commercial catalytic refining processes, such as Platformer (U.O.P), Power-former (ESSO) and Houdri-former (Houdri), that are available, a process best-suited to meet our requirements will have to be chosen. Toluene content in the reformat is higher than the benzene content, but the demand for benzene is greater than for toluene. By

selection of proper fractions it would be possible to rectify this imbalance. Higher yields of benzene than toluene are possible if the feed-stock contains C_6 cuts only. If the feed-stock contains components up to C_8 then the yield of toluene and xylenes would be twice that of benzene. It is a common practice to operate the catalytic reformer to produce either benzene/toluene or xylenes. For optimum utilisation of a plant, a combination of both is often achieved by running the appropriate light and heavy naphtha cuts through the same plant in blocked operations. These factors would have to be taken into consideration while basing the production of aromatics on petroleum sources.

31. Crudes rich in naphthenes are best-suited for the manufacture of aromatics. The crudes refined at present in India are imported from the Middle East and these contain comparatively small quantities of naphthenes since these are mixed base. We would have a very good source of crude for the manufacture of aromatics in the Nahorkatiya crudes which are very rich in aromatic as well as naphthenic hydro-carbons, but this would be in an area where benzene from coal carbonisation would be available in substantial quantities.

32. Since there is likely to be a shortage of benzene in the country, it is necessary that the indigenous crudes are suitably processed for the recovery of aromatics. The question of recovery of aromatics either by straight separation or preferably after catalytic reforming deserves careful consideration.

33. While the light gasoline fraction of Cambay crude is reported to contain 18.2% naphthene and 4.2% aromatics the light fraction of Ankleshwar crude is reported to contain 32.2% naphthenes and 10% aromatics. These crudes, particularly the Ankleshwar one, also appear to be suitable for the production of aromatics. Since the demand for benzene for projects already sanctioned in the Western-region of the country is about 20,000* tons/year and the two naphtha-cracking units in that region would only meet about half of this requirement there is need for additional benzene which can be met either by expanding the capacity of naphtha crackers already sanctioned and/or by the catalytic reforming and isolation of aromatics. In this context the production of aromatics from Ankleshwar crude in the new refinery would deserve careful consideration.

34. There would be certain obvious advantages in a refinery itself setting up a catalytic reformer, because the non-aromatic fractions of a reformate could be used with advantage by a refinery for gasoline blending. This would influence the economics of the aromatics plant as well as the refinery. Similar considerations would hold good in respect of steam-crackers also. Under exceptional circumstances, however, a steam-cracker may have to be set up independently. Since the plants for the manufacture of aromatics are capital intensive, it is essential to ensure that the units are of economic size because it is important that the products are made available

*(The full demand is expected to develop during the early part of the Fourth Plan).

to other industrial consumers at prices comparable with world prices for these commodities or in competition with supplies from steel plants in the country. In addition to methane, propane, butanes and pentanes, considerable quantities of hydrogen would become available as by-product and this would have to be utilized to the best advantages.

35. The aromatics are recovered by the UDEX, sulphurdioxide or sulfone extraction process. Benzene, toluene and xylenes are separated by fractional distillation. Because of the wide boiling range between benzene and toluene, nitration grades of benzene and toluene could be obtained by distillation. O-xylene can be separated from the M-P-xylenes by fractionation and the latter by adductive crystallisation process using carbon tetra-chloride.

Toluene

36. Compared to benzene, the demand for toluene is rather limited. Toluene will be needed to meet the requirements, mostly of Defence (for TNT) and the requirements of intermediates for the dyes, drugs and pharmaceutical industries. It is used as a solvent; it also finds use in aviation and motor gasoline. The demand for toluene envisaged at about 4000-5000 tons by the end of the Third Plan may increase to 6000-7000 tons by the end of the Fourth Plan. If the production of phenol/caprolactum is based on toluene, the demand by 1970 may rise to about 20,000 tons. Such possibilities appear to hold promise in the light of recent developments in other countries.

37. As against an estimated demand of 5,000 tons of toluene by 1965-66, the availability of toluene from coal carbonisation units by them would be about 16000-17000 tons. To this must be added additional quantities of toluene that would become available from the catalytic reformers. It is, therefore, evident that toluene would be in large surplus and its disposal would pose a problem. A solution to this problem can be found either by adding it to motor gasoline as high octane component or by its conversion to phenol, as well as to benzene by de-alkylation with hydrogen. Exports, if feasible will also provide another outlet. These aspects would need further examination.

Xylenes

38. While there would be a good demand (about 10,000 tons by 1965-66 and 30,000 tons by 1970-71) for O-xylene (for conversion to phthalic anhydride), the demand for P-xylene would be very limited. There might even be a shortage of O-xylene. Disposal of M-xylene would also be a serious problem. It may, however, go back to the gasoline pool. It might also become necessary to adopt processes for the isomerisation of M-xylene to O-xylene and P-xylene mixture and thus reduce the magnitude of the problem. These problems are not likely to assume importance during the Third Plan.

Naphthalene

39. Naphthalene is yet another aromatic hydro-carbon of considerable importance. The demand for naphthalene is expected to increase

from 20,000 tons by the end of the Third Plan period to 40,000 tons by the end of the Fourth Plan, as indicated in the table below:

(Tons per year)

S. No.	Item of manufacture	1965-66		1970-71	
		Qty. of product	Qty. of naphthalene required	Qty. of product	Qty. of naphthalene required
1. <i>Phthalic Anhydride</i>					
(a) for Alkyd resins		3,000		6,000	
(b) for plasticisers		6,000		15,000	
(c) for Dyestuffs		3,000		4,500	
(d) for Polyesters		500		1,500	
(e) for Misc. uses		500		1,500	
		13,000	16,000	28,500	34,000
2. Dyestuffs		—	2,300	}	6,000
3. Misc. uses		—	1,700		
			20,000		40,000

As against the demand indicated in the table above, it is expected that about 12,500 tons of naphthalene will definitely become available from the coal carbonisation units by 1965-66. The gap between demand and supply would have to be bridged by the use of alternative starting material, namely O-xylene for the production of phthalic anhydride (it may be noted that over 80% of naphthalene would be needed for the production of phthalic anhydride). The production of naphthalene from petroleum fractions rich in alkyl-naphthalenes by catalytic de-alkylation would also provide a solution to the problem but such fractions are unlikely to be available in the country. It may be pointed out here that the commercial production of naphthalene from petroleum products is on its way for the first time even in U.S.A.

Ethylene and Propylene

40. The demand for ethylene from petroleum sources (after taking into consideration the extent of utilisation of alcohol based-ethylene) would be of the order of 47,000 tons by 1965-66 and this is expected to increase to 165,000 by 1970-71. In the case of propylene the demand is estimated to increase from 18,000 tons in 1965-66 to 70,000

tons by 1970-71. The diverse products on the manufacture of which these estimates are based are given in the tables below:—

ETHYLENE

Usage Excluding production based on ethyl alcohol	1965-66		1970-71	
	Qty. of product	Qty. of ethylene required	Qty. of product	Qty. of ethylene required
1. Polyethylene	27,500	30,000	108,000	120,000
2. Styrene	7,000	3,000	29,000	120,000
3. Ethylene oxide including use as glycol and glycol derivatives Ethanolamine, syndets. (Acrylonitrile is not likely to be based on ethylene and so not included).	5,000	5,000	10,000	10,000
4. Vinyl chloride, Ethylene dichloride Ethyl Chloride and others ..	9,000 6,000	8,000	—	18,000
5. Acetaldehyde & Derivatives ..	—			
6. Ethyl alcohol	—	—	—	5,000
TOTAL ..		47,000		165,000

PROPYLENE

Usage	1965-66		1970-71	
	Qty. of product	Qty. of propylene required	Qty. of product	Qty. of propylene required
1. Polypropylene	4,000	4,500	20,000	22,000
2. Low mol. weight polymers (nonene and dodecene for Dodecyl benzene, Alkyl phenol and others.	—	3,000	—	15,000
3. Acetone Direct solvents such as Diacetone, MIBK etc. Methyl methacrylate Bis-Phenol Chemical uses ..	9,500	6,000	18,000	15,000
	Out of which 3,000 tons may be produced from ethyl alcohol.			3,000 less from ethyl alcohol
4. Isopropanol-(Solvent, acetate epi-chlorhydrin and Misc.)	2,000	1,000	10,000	5,000
5. Acrylonitrile	—	1,500	—	5,000
6. Oxochemicals	—	500	—	3,000
7. Miscellaneous	—	500	—	3,000
TOTAL ..	—	18,000	—	70,000

41. The two steam-crackers which have already been approved in the Bombay region are expected to provide about 35,000 tons of ethylene and about 25,000 tons of propylene per year on the basis of current licensed capacity of 160,000 tons of naphtha throughput. (Although the steam-crackers would be installed mainly for providing basic olefins, namely ethylene and propylene, certain quantities

of butylenes, butadiene and aromatics (benzene) also become available as by-products. The aromatic content in a steam-cracked naphtha is much lower than from the catalytic reformer.) It is evident that further step-up of steam-cracking facilities would be needed even during the Third Plan *vis-a-vis* the demand forecasts for ethylene and propylene.

Synthetic Rubber

42. The production of indigenous raw rubber in the plantations in South India has not been able to keep pace with the rapidly increasing demands of the Rubber-goods Manufacturing Industry. The gap between demand and supply of rubber has been steadily widening; the gap of 6,243 tons in 1954 has increased to 32,638 tons in 1960. The relevant figures are given in the table below:—

Consumption of rubber by the Rubber-goods Manufacturing Industry.

(Figures in tons)

Year	Natural Rubber	Synthetic Rubber	Reclaimed Rubber	Total	Production of natural Rubber	Deficit
1954	25,487	19	2,230	27,736	21,493	6,243
1955	27,543	106	2,502	30,502	22,481	7,670
1956	28,996	2,409	3,261	34,666	23,444	11,222
1957	31,765	3,032	3,837	38,634	23,767	14,867
1958	34,755	3,044	4,044	42,051	24,328	17,723
1959	38,663	4,342	4,454	47,459	23,398	24,061
1960	45,941	6,561	5,328	57,830	25,192	32,638

43. In order to bridge this gap between demand and supply, the following steps had been taken:—

- (1) To increase the production of raw rubber, replantation and new plantations have been undertaken in South India with the assistance of the Government. The Working Group on Rubber set up by the Union Ministry of Commerce and Industry has, after studying these aspects in detail in consultation with all interests concerned, estimated that production of natural rubber would be increased from the current (1960) level of production of 25,000 tons to 40,800 tons in 1965, to 55,000 tons in 1970 and to 82,400 tons in 1975.
- (2) Two schemes for the manufacture of synthetic rubber have been approved and licences have been issued. The first scheme relates to the manufacture of 30,000 tons/year of SBR synthetic rubber near Bareilly in Uttar Pradesh, the chief raw materials being alcohol and benzene. This scheme has been making satisfactory progress and the unit is expected to go into production by the middle of the next year. The other scheme relates to the manufacture of 20,000 tons/year of Cis-4-Polybutadiene, a new type of synthetic rubber in Assam based on the higher fractions

of the natural gases of the Assam oil-fields. This scheme has not made much progress and is unlikely to be implemented, due to non-availability of raw materials in adequate amounts.

- (3) Steps have been taken to license units for the manufacture of reclaimed rubber from worn out tyres, tubes, etc. and it is estimated that about 20,000 tons of reclaimed rubber will become available by 1965-66 and 40,000 tons by 1970-71.

44. The current production of 1.47 million automobile tyres and 10.8 million bicycle tyres would increase to 4 million and 30 million Nos. respectively by the end of the Third Plan, if the revised targets suggested by the Ministry of Commerce & Industry for automobile tyres are approved and further expansion of capacity effected. Corresponding to this rate of increase in production, the consumption of all varieties of rubber would increase from 57,830 tons in 1960 to about 141,000 tons in 1965-66 and to about 280,000 tons by 1970-71. As against this requirement, natural and reclaimed rubbers to the extent of 60,000 tons in 1965-66 and 95,000 tons in 1970-71 would be available from indigenous sources leaving a gap of 80,000 tons and 205,000 tons by the end of the Third and the Fourth Plans respectively. Due to technological reasons it may be necessary to import 10,000 tons of natural rubber during 1965-66 and 5,000 tons in 1970-71. Gap to the extent of 70,000 tons in 1965-66 and 200,000 tons in 1970-71, therefore, would have to be bridged by the manufacture of synthetic rubber. The quantum may have to be reduced if, in the interests of export drive in the South Eastern Region of Asia, imports of natural Rubber have to be accepted as part of bilateral trade arrangements.

45. A variety of synthetic rubbers are made commercially in U.S.A. and other countries and new ones are being developed. Our interest would be in the manufacture of what are known as "general-purpose synthetic rubbers" which would be required in large quantities (the demand for special-purpose synthetic rubbers is small). It is not easy to forecast the exact ratio in which the different general-purpose synthetic rubbers would be needed, but a broad indication for planning purposes can be given based on the characteristics of the rubbers and our requirements.

46. As indicated earlier, steps have already been taken for the manufacture of SBR rubber to the extent of 30,000 tons/year. It is fairly clear that there would be no need for creating additional capacity for SBR type of synthetic rubber, since it cannot be used alone or in substantial quantities in admixture with natural rubber in the manufacture of giant tyres (due to hysteresis heat build-up and ply separation) which would continue to constitute the bulk of the automobile tyres produced in the country for a fairly long time to come. In view of the limited availability of natural rubber from the plantations in the South, the need is for manufacture of that type of general-purpose synthetic rubber which would need the least amount of natural rubber for compounding. On this score, the claims of the two stereo-specific rubbers, namely Cis-4-Polybutadiene and Cis-polyisoprene, deserve careful consideration. Many experts think

that polybutadiene will ultimately become the number one tyre rubber. Although at present it is being used to substitute natural rubber to the extent of 50% companies are beginning to come out with 100% polybutadiene tyres. Poly-isoprene, which at best can duplicate natural rubber, lacks the natural rubber's good adhesion for tyre building. With regard to butyl rubber, its superiority over synthetic rubbers and natural rubber in the manufacture of automobile tubes due to its very low air-permeability is well-known and efforts are being made to modify it such that it can be used as general-purpose rubber. Butyl-rubber has poor wear characteristics when used for making tyres.

47. Butyl and the still experimental Ethylene-propylene Copolymer have the lowest raw material cost, but this advantage may be more than off-set by the fabrication costs which are reported to be high. The next, most expensive raw materials go into the production of SBR followed by poly-butadiene. The most expensive raw materials are needed for the production of poly-isoprene. The use of poly-isoprene is likely to increase substantially if the claim that a process has been developed recently in the U.S.A. for producing poly-isoprene synthetic rubber is substantiated by actual commercial production.

48. The competition between the different types of synthetic rubbers will become more complicated before a victor clearly emerges. It is in this context, having regard to the availability of raw materials from indigenous sources and the inter-changeability of the newer synthetic rubbers, that one has to decide the type as well as the quantities of synthetic rubbers which are to be manufactured in the country.

49. As compared to the pattern of consumption of 1955 and 1960, the pattern of consumption of rubber by the Rubber-goods Manufacturing Industry in 1965 and 1970 may be as indicated in the table below:—

		(Figures in tons/year)			
Type of Rubber		1955	1960	1965	1970
1. Natural Rubber		28,000	45,941	*50,000	**60,000
2. SBR (Styrene-Butadiene Rubber)		108	6,561	30,000	30,000
3. Reclaimed Rubber		2,500	5,328	20,000	40,000
4. Cis-4-Polybutadiene		—	—	30,000	80,000†
5. Poly-Isoprene		—	—	—	30,000†
6. Butyl Rubber		—	—	10,000	30,000†
7. Other special types of rubber, such as neoprene, acrylonitrile, etc.		—	500	1,000	10,000
TOTAL ..		30,608	58,330	141,000	280,000

*40,000 (Indigenous) plus 10,000 (Imported).

**55,000 (Indigenous) plus 5,000 (Imported).

† The demand for 4, 5 and 6 are interchangeable.

This pattern of consumption which will influence the production of different types of synthetic rubbers will require a review in consultation with the principal consumer interests at the appropriate stage.

Butane/Butylenes

50. The requirement of butane and butylenes is mainly dependent on the targets set for the synthetic rubber in the above table. In working out the raw material requirements of poly-isoprene it has been assumed that the production of isoprene will be based on iso-butylene (from a C₄ cut) which would be catalytically reacted with formaldehyde. (The process employed for the manufacture of isoprene may be different, e.g. its production may be based on propylene. There would, therefore, be variation in the raw material requirement depending on the process adopted).

51. Besides the synthetic rubbers, other chemicals derived from butane/butylenes are Secondary Butyl Alcohol, Methyl Ethyl Ketone, Butyl Phenols, Iso-octane for gasoline blending, Di and Tri-isobutylenes for some special products like lubricants, additives etc. Iso-butylene is also reported to be used in a new process for Methyl Methacrylate.

52. Taking the above aspects into consideration a rough estimate of the butane/butylene requirements in 1965 and 1970 is worked out below:—

Item/Usage	1965		1970		Remarks
	Qty. of product	Qty. of C ₄ hydro-carbon required	Qty. of product	Qty. of C ₄ hydro-carbon required	
(1)	(2)	(3)	(4)	(5)	(6)
SBR ..	tons 30,000	only (all derived from alcohol—already licensed)			
Cis-4-Polybutadiene.	tons 30,000	60,000/ 45,000 tons of N-Butane/N-Butylene	80,000	160,000/ 120,000 of N-Butane/N-Butylenes.	20,000 tons licensed Assam.
Butyl Rubber ..	10,000	11,000 tons of ISO-butylene	30,000	33,000 tons of ISO-butylene.	A unit of 20,000 tons capacity may be planned even for 1965.
Poly-isoprene	—	—	30,000	Isobutylene 30,000 tons Methanol- 26,000 tons.	Other raw material may be used 70,000 tons of propylene for Good-year S.D. process.

(1)	(2)	(3)	(4)	(5)	(6)
Secondary Butyl-Alcohol & Methyl Ethyl Ketone.	1,000 tons	1,000 tons of Iso-butylene.	3,000 tons	3,000 tons of Iso-butylene	
Alkyl Phenols, Oxo-alcohol, Poly-butenes, etc.	—	600 tons of Isobutylene	—	1,500 tons Isobutylene.	
Iso-Octane ..	—	—	—		May not be required in view of current trends in aviation and lower C/R of automobiles in India.

60,000/45,000 tons-N-Butane/N-Butylenes 160,000/120,000 tons-N-Butane/N-Butylenes. 13,000 tons/Isobutylene 67,500 tons/Isobutylene.

Synthetic Detergents

53. There are three types of synthetic detergents, namely, Anionics, Non-ionics and Ampholytics. Amongst the Anionics, sodium Dodecylbenzene sulphonate is the best-known synthetic detergent. The more important Non-ionic detergents are derived from ethylene-oxide and the best-known example of this class of synthetic detergents is Nonyl Phenol-polyethylene-oxide. Ethylene-oxide is the most important raw material needed for making the Non-ionic detergents. Ampholytics are relatively new-comers in this field and they behave like cations in acid solution and like anions in alkaline solutions. Salts of N-alkyl B Amino-propionates are examples of this class of synthetic detergents.

54. Although many synthetic detergents are known, the biggest selling synthetic detergent is still 'Sodium dodecyl-benzene sulphonate' and, therefore, it would be appropriate to undertake its manufacture in India.

55. In fixing the levels of production of synthetic detergents the production and consumption pattern of soap and synthetic detergents in the U.S.A. would be useful:—

Year	Production (million lbs.)			Civilian per capita consumption (lbs.)		
	Synthetic detergent	Soap	Total	Synthetic detergent	Soap	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1940	30	3,273	3,303	—	25	25
1942	50	3,648	3,698	1	26	27
1945	150	3,888	4,038	2	25	27
1950	1,443	2,958	4,401	9	19	28
1954	2,488	1,760	4,228	13	12	25
1957	3,507	1,432	4,939	20	8	28

						Wholesale Price Index	Synthetic Detergents
						Soap	
1952	..	..	..	..	..	87.8	91.3
1954	..	..	..	..	..	96.0	93.0
1957	..	..	..	..	..	104.5	99.0

56. It would be noticed that during a period of twelve years (1945 to 1957) the consumption of synthetic detergents has increased ten-fold and during the same period the consumption of soap has been reduced to a third in U.S.A. Whether a similar trend will manifest itself in India has to be carefully considered.

According to the Draft Outline of the Third Plan, the production of Soap would increase from 380,000 tons in 1960 to 500,000 tons in 1965-66. During the same period, the production of synthetic detergents is expected to increase from 2,000 tons to about 24,000 tons/year (corresponding to about 8,000 tons dodecyl-benzene). It is likely that the rate of increase in the production of synthetic detergents would be faster than what is contemplated in the Third Plan Draft Outline. By 1970-71 the demand for synthetic detergents may be expected to increase to 90,000 tons (corresponding to 24,000 tons of dodecyl-benzene). The per capita consumption of soap in India is so small that the production is unlikely to fall to any appreciable extent so long as the present allocations of foreign exchange in respect of import of coconut and palm oils is continued. It is evident that production of detergents from indigenous starting materials would be cheaper in terms of foreign exchange than the production of soap from imported coconut and palm oils.

Carbon Black

57. The demand for various grades of carbon blacks by 1965-66 would be as under :—

						million lbs.
(a) Rubber-goods Manufacturing Industry	..	..	..	..	..	70
(b) Ink, paints and other Industries	..	..	..	..	..	10
(c) Exports	..	..	..	..	..	10
TOTAL						90

On the basis of an operational efficiency of 80%, the capacity that would be required to achieve a production of 90 million lbs. would be about 113 million lbs. As against this, the capacity that has been licensed/approved as per details given below adds up to 80 million lbs. per year:—

						million lbs/year
(1) M/s. Duncan Brothers, Calcutta (Phillips Carbon Black)	..	..	..	..	..	30
(2) M/s. P. J. B. Industries, Calcutta	..	..	..	..	..	20
(3) Shri C. H. Bhabha, Bombay	..	..	..	..	..	30
TOTAL						80

58. M/s. Duncan Brothers project at Durgapur (West Bengal) is based on the utilisation of coal-tar as the raw material. M/s. P. J. B.

Industries would be locating their unit for the manufacture of Furnace type carbon black in Assam based on the Nahorkatiya natural gases. The third unit would be established in the Bombay region. This unit would be based on the feed-stocks that would become available from the lubricating oil plant to be set up in the Bombay region. All the three projects have been undertaken in technical and financial collaboration with well-known carbon black manufacturers in U.S.A. Parties mentioned at (2) and (3) above have undertaken to export a part of their production. Capacity for the manufacture of an additional quantity of about 30 million lbs. of carbon black, to meet the anticipated demand by the end of the Third Plan period, would have to be based on the availability of suitable feed-stocks from indigenous sources. (The availability of suitable feed-stocks for the manufacture of carbon black has been discussed in Chapter III.)

59. It is estimated that the current demand of about 6 million lbs. of Channel type carbon black might increase to about 10 million lbs. by 1965-66. The manufacture of Channel Black all over the world is based on the utilisation of the natural gases. One possible location, therefore, for the manufacture of Channel type carbon black would be the Nahorkatiya region. A carbon black unit of this type throws up large quantities of fine carbon black particles into the atmosphere so much so the atmosphere over a large area is polluted with fine carbon particles. Fears have been expressed that carbon black particles might adversely effect the tea plantations and the tea in Assam. Since the tea plantation industry earns a considerable amount of foreign exchange by the export of tea, it is essential to see that this industry is not exposed to the hazards due to atmospheric pollution. On this ground, the location of a channel type carbon black unit in Assam would have to be ruled out. The manufacture of this type of carbon black could be undertaken if adequate quantities of natural gas become available at a suitable location in the country.

CHAPTER V

Facilities needed for the Manufacture of Organic Chemicals and other Products and Related Matters

The extent to which alcohol from fermentation of molasses and benzene, toluene, xylenes and naphthalene from the coal carbonisation units would become available for the manufacture of organic chemicals and other associated products has already been indicated in the previous Chapters. Of the products from the refineries, as indicated in Chapter III, very little of refinery gases and gases from catalytic cracking/reformed units would be available, as these gases are used either as refinery fuel or are ear-marked for use in the manufacture of nitrogenous fertilizers along with naphtha. It is only at the Gauhati refinery that a certain amount of surplus Aromex will be available. At the Gauhati refinery Aromex I to the extent of 36,000 tons/year and Aromex II to the extent of 28,200 tons/year would be produced. Except for a very small quantity of Aromex I, which would be needed for blending with gasoline to increase its Octane number, no other use has been envisaged at present for Aromex I and Aromex II. These products to the extent of about 50,000—60,000 tons/year would, therefore, be available for the manufacture of organic chemicals. Since the availability of natural gases (associated as well as non-associated) in the Nahorkatiya-Moran Oil-fields is limited, surplus naphtha would be the chief raw material for the manufacture of naphtha and the natural gases and their proper utilisation are examined below:—

Uses for Surplus Naphtha

2. The surplus naphtha likely to be available each year from 1960 to 1966 was indicated in Chapter II. The relevant figures are as follows:—

year	सन्तुलन नयने					Surplus Naphtha
1960	..	..	..	..	..	209,000
1961	..	..	..	..	..	152,000
1962	..	..	..	..	..	270,000
1963	..	..	..	..	..	503,000
1964	..	..	..	..	..	553,000
1965	..	..	..	..	..	973,000
1966	..	..	..	..	..	899,000

From these figures it would appear that the greatest surplus of naphtha would occur in 1965 and that it would go down gradually in subsequent years. As already pointed out, additional refining capacity would have to be brought into existence during the Third and Fourth Plans and this would naturally release additional quantities of naphtha. It is, therefore, evident that the disposal of naphtha would be a problem, since the imbalance in the demands and production of motor spirit is likely to continue.

3. The most profitable uses of surplus naphtha would be as a raw material for production of materials that would save maximum foreign exchange. Such materials are nitrogenous fertilizers, petrochemicals and town gas for substitution of kerosene as a domestic fuel. The alternative suggestion is to use naphtha in admixture with gas oil. However, before marketing any such blend some administrative problems would have to be solved.

4. Since a ton of naphtha costing about Rs. 73 per ton at the refinery (exclusive of excise duty) can produce a ton of nitrogen as fertilizer and the c.i.f. value of imported fertilizer is approximately Rs. 1,000 per ton of nitrogen, use of naphtha for fertilizer production would save foreign exchange equivalent to about ten times its value. Similarly, when naphtha is used for production of organic chemicals, plastics, etc. the value of the material produced per ton of naphtha would vary from three to seven times the cost of naphtha depending on the nature of the ultimate product. In view of this and also in view of the imperative need to make the country self-sufficient with regard to food-stuffs by increasing the yield per acre by the use of fertilisers, steps have already been taken to produce additional quantities of nitrogenous fertilizers based on naphtha. Simultaneously, steps have also been taken to produce organic chemicals and other products from petroleum products.

Nitrogenous Fertilizers

5. The likely requirement of naphtha for production of nitrogenous fertilizers in factories already licensed/approved as well as under consideration is given below:—

Project]	Annual production capacity (Tons-N)	Production based on naphtha (Tons-N)	Likely date of commencement of production.
I. Units Already Licensed			
(1) East India Distilleries, Madras (Private Sector)	8,000	8,000	End of 1962
(2) FACT, Alwaye (Private Sector)	60,000	50,000	End of 1963
(3) Trombay (Public Sector)	90,000	45,000	End of 1964
(4) Vizag (Private Sector)	70,000	70,000	End of 1964
		173,000	
II. Units Approved			
(1) Gorakhpore (Public Sector)	80,000	80,000	End of 1964
(2) Cambay or Ankleshwar (Public Sector)	80,000	40,000	End of 1964 early 1965
		120,000	

Project	Annual production capacity (Tons-N)	Production based on naphtha (Tons-N)	Likely date of commencement of production
III. Units under consideration			
(1) Tuticorin (Private Sector)	*33,000	*33,000	
(2) Mangalore.	70,000	70,000	
		103,000	
Total of I, II and III above.		173,000	
		120,000	
		103,000	
		396,000 tons-N	

*The question of raising these figures to 60,000 is under consideration.

6. In addition, the units to be established in Madhya Pradesh (50,000 tons-N) and Rajasthan (60,000 tons-N) might decide on the use of naphtha if it is available at a price that would permit production of ammonia at a cost comparable with that from coal or lignite.

7. The approved project for the supply of 20 million cu. ft. per day of domestic gas to the city of Bombay by the Trombay Fertiliser unit would consume naphtha to the extent of 95,000 tons/year.

8. Thus, for production of nitrogenous fertilizers and town gas nearly 491,000 tons of naphtha have already been ear-marked. This would, therefore, leave a quantity of about 400,000 tons for the manufacture of organic chemicals.

Steam-crackers and Refinery in South India

9. The setting up of a captive steam-cracker (capacity 60,000 tons/year) for the production of ethylene, propylene and benzene needed for the manufacture of polyethylene, organic chemicals and solvents has already been licensed in the Bombay region. Another proposal for setting up a steam-cracker (capacity 100,000 tons/year of naphtha) has also been licensed. While the first unit has applied for permission to increase its capacity to 85,000 tons/year, the second has sought permission to expand its capacity to 200,000 tons/year. It would be advantageous to permit them to expand their capacity to the extent requested by them if the targets for plastics etc. indicated in the report are accepted. Even otherwise, the expansion of the cracking facilities would merit favourable consideration, since by doing so opportunities would be created for the production of organic chemicals of high priority which are in short supply, e.g., synthetic rubber and methanol as well as recovery of benzene in proximity to a major centre of its consumption, viz. Bombay area. It would be necessary further to set up three more cracking units, one in the eastern part of the country based on the naphtha from the Barauni refinery, another in Gujarat and a third in South India. In case adequate quantities of surplus naphtha are not available for these

projects, the shortfall would have to be made good by imports till the indigenous supply catches up with demand, because it would cost much less foreign exchange to import naphtha than the import of the finished products derived from it. Here again, it would be advantageous to import suitable crudes and make available the naphtha for the chemical industry after refining because this would ensure foreign exchange saving in the refining cost and in addition make available several other products needed in the country.

Size of Cracker

10. With regard to the size of a cracker, some representatives of firms who met the Committee, emphasized that they were of the view that it would be more advantageous to put up a few large naphtha-cracking units rather than putting up a large number of small units which would not be as economical as the larger units. In this connection, they mentioned that the minimum economic size for a cracker, would be 100,000 tons/year. They emphasized that there would be a considerable saving in foreign exchange as well as in the total investment if a big cracker is established. To illustrate the point, they gave the following figures:—

tons/year	Investment per ton on naphtha cracked
25,000	Rs. 950
100,000	550
200,000	400

Certain other representatives of firms, who also met the Committee, expressed the view that a Lurgi unit of 10,000/20,000 tons throughput could be regarded as of economic size if the products desired are mainly acetylene and ethylene. If on the other hand, the products desired were to conform to a complete spectrum, the capacity might have to be 60,000 tons/year or more.

11. While discussing the economics of ethylene manufacture in a Kellogg cracker the Committee's attention was invited to the point that a cost of 5.28 cents indicated per lb. of ethylene was unrealistic because the investment on off-sites had not been taken into account. ("Economics of Ethylene manufactured from Light Naphtha"—Journal of Institute of Petroleum, November 1960.) If this factor is also taken into account, it was stated that the cost of ethylene would go up by about 30%. As none of the members of the Committee had first-hand experience of the relative merits and demerits of the different types of crackers as also the minimum economic size for such crackers, the Committee is not in a position to express any firm opinion on these aspects. The Committee, however, is of the view that in a large country like India, where there are few refineries, there might be scope for setting up large as well as small crackers. The choice of the type of cracker as well as its size would have to be determined after taking into consideration all relevant factors.

12. With a view to ensure balanced development of different parts of the country and also to minimise the transport of chemicals and finished products that would be needed in the various regions of the country, it would be necessary to set up naphtha-cracking units in

the different regions. Since these crackers would have to draw naphtha from the refineries, it stands to reason that while setting up new refineries the natural supply area, would have to be taken into consideration. In this context, it would be necessary to set up a refinery in South India. This would obviate the need for the transport of naphtha from Bombay to the F.A.C.T., Alwaye and also would help in setting up Petro-chemical Industry in South India to meet the requirements of that region.

13. A large unit could only be set up in a few places in the country because such a unit will have to be located near a refinery. This is so, because the need for transport of large quantities of naphtha over long distances would not arise. Secondly, some of the unutilized products of the cracker could be returned by the cracking unit to the refinery for proper utilization. A larger unit would, for its economic operation, depend on the utilization of all the products obtained from it and this may not be possible in certain parts of the country where Chemical Industry has not made sufficient progress. A smaller unit would not have this disadvantage and it could be located even in places which are far away from the refinery. The decision regarding the size of a unit should be based on economic considerations as well as the practical possibilities in the different regions of the country. While encouraging the setting up of crackers as well as other units for the production of organic chemicals and other products during the Third and the Fourth Five-Year Plans every attempt must, therefore, be made to see that the cost of production is as low as possible and this could be ensured by setting up a few units with large capacities rather than licensing a large number of small units. This would result in products of such units having a lower cost of production comparable with the cost of production in other industrially advanced countries. The industries would then have a firm footing within the country and their products would offer considerable scope for organising the exports at least to the neighbouring countries.

Location of Crackers

14. Amongst the starting raw materials derived from the petroleum origin, olefines are perhaps the most important grouping of 'building blocks' needed for the manufacture of synthetic organic chemicals and related products. Amongst the olefines, ethylene is perhaps the most important member. It has already been indicated that ethylene to the extent of 165,000 tons would have to be obtained from petroleum sources by the end of the Fourth Plan period. As already indicated, generally steam-cracking units are established primarily for the production of olefines and in such units the production of ethylene is of the order of about 22% on the amount of naphtha cracked. The minimum economic size of a steam-cracker would be of the order of 200,000 tons of naphtha throughput per year. A unit of this size would produce various starting materials needed for the production of finished products in units of economic size.

15. From the above considerations, it would be clear that there is need for setting up four steam-cracking units in the country to meet the requirements of ethylene, propylene, butylenes, butadiene, benzene, tail gases, etc. From economic consideration it is essential to

establish steam-cracking units near a refinery. This is so because such a step would avoid the need for transport of naphtha over long distances. Secondly, some of the uncracked liquids from the steam-cracker as well as certain other products, which cannot be utilised for production of chemicals, could be returned with advantage to the refinery for proper utilization. It is also necessary to set up steam-cracking units in the Western, Eastern, and Southern zones of the country in order to meet the requirements of organic chemicals and finished products in these regions. From these considerations it would follow that a steam-cracker should be established near the refineries in Bombay. Similar consideration would hold good with regard to a second steam-cracker to be established in conjunction with the Barauni refinery in the eastern region. A third steam-cracking unit could be established in Gujarat when the refinery is set up there. A fourth steam-cracker would have to be set up somewhere in South India in conjunction with a refinery in that region. The need for setting up a refinery in South India has already been referred to earlier in Chapter III. From chapter III on "Availability of Raw Material Feed-stocks" it would be seen that by the end of the Third Plan period while there would be a surplus of motor gasoline, there would be heavy deficits in respect of middle distillates such as kerosene, high-speed diesel oil, light diesel oil, fuel oil etc., and also of other products. This deficit could be met either (a) by imports of these products or (b) by undertaking additional refining of indigenous or imported crudes in South India. The latter step would have to be preferred because it would cost much less foreign exchange and in addition would make available motor gasoline and surplus naphtha for the Petro-chemicals Industry. It would be desirable to plan a refinery of economic size in South India from now and base the same on imported crudes. The refinery could switch over to the use of indigenous crudes if additional quantities of oil are found in South India.

16. A steam-cracker would provide essentially olefines and a certain quantity of aromatics. Utilizing these starting materials it should be the endeavour to build up a petro-chemical complex involving the manufacture of diverse products keeping in view the estimated demands indicated by the end of the Third and the Fourth Plan periods. As an illustration, it may be mentioned here that such a unit has been kept in view while licensing capacity in respect of petro-chemicals in the Bombay region. It is anticipated that permission would be granted for setting up a steam-cracker of capacity of 200,000 tons/year in the Bombay region. Steps are being taken to build up a petro-chemical complex around the steam-cracker involving the production of the following products.

					Production	Ex-Factory Value
					tons	Rs. lakhs
(1) High density Polyethylene	..	..	..	..	8,400	310
(2) Vinyl Acetate Monomer	..	..	..	..	4,800	94
(3) Ethylene Oxide	..	..	..	..	3,600	75
(4) P.V.C. (inclusive of production of National Organics and Calico expansion only)	..	..	..	..	8,400	175

							Production	Ex-Factory Value
							tons	Rs. lakhs.
(5) Benzene	..	..	..	..	..	..	14,000	60
(6) Methanol	..	..	..	..	..	..	20,000	80
(7) Acetone	..	..	..	..	..	..	6,000	60
(8) 2-Ethyl Hexanol	..	..	..	..	..	..	3,600	90
							(from Acetaldehyde) (by Union Carbide)	
(9) Synthetic Rubber	..	..	..	..	..	..	20,000	700
TOTAL VALUE							..	1,644
								or Rs. 16.44 crores

It is also intended that the steam-cracking unit in the Bombay region would be of the high severity type.

17. It is necessary to build petro-chemical complexes around the other three steam-crackers in other parts of the country. Depending upon the products to be included for production in these petro-chemical complexes it would be necessary to decide whether steam-crackers would be of the low severity type or of the high severity type. It might be mentioned here that if the steam-cracker is of the low severity type, there is a higher production of propylene and of a somewhat lower production of benzene and ethylene. On the other hand, in a high severity cracker the production of propylene would be lower and of benzene and ethylene higher.

18. The demand for N-butane/N-butylenes would increase from about 45,000 tons by the end of the Third Plan period to about 120,000 tons by the end of the Fourth Plan period. Similarly, the demand for iso-butane/iso-butylenes would rise from about 13,000 tons to 65,000 tons. These C₄s would be required for the production of synthetic rubbers. It is understood that substantial quantities of C₄s available at the Barauni refinery are intended to be sold as LPG. It is also understood that there are plans for the production of LPG at the Gauhati refinery also. Rubber being a material of strategic importance, it would be necessary to divert all the C₄s for the production of synthetic rubber than use C₄s as fuel in LPG. It might also be necessary to plan a special type of naphtha-cracking unit to produce C₄s required for the production of synthetic rubber somewhere in North India.

Production of Aromatics from Petroleum Feed-stocks

19. The requirements of benzene would rise from about 80,000 tons by the end of the Third Plan period to about 170,000 tons by 1970-71. As against this, the potential availability of benzene on a long-term basis from the coke-ovens, taking into consideration the proposal for expansion of Steel Industry during the Third Plan also, would be of the order of 50,000 to 60,000 tons per year by the end of the Third Plan, and about 100,000 tons by the end of the Fourth Plan. It is, therefore, obvious that there will be a gap between the demand and supply of benzene and this gap would have to be bridged by the production of benzene from petroleum sources. Since the demand for benzene would be of the order of 170,000 tons

by 1970-71, it is obvious that the production of aromatics from petroleum derivatives and their recovery will assume an even greater significance during the Fourth Plan period.

20. Benzene needed for the schemes, which have already been approved in the western region, should be approximately 4.93 million gallons per year (about 20,000 tons) as per details given below:—

BENZENE—Estimate of main requirements for the Western Zone

Firms	Requirements (Mill. gals/year)	Purpose
(1) Central Intermediates Plant	2.55	Intermediates manufacture.
(2) M/s. Hindustan Insecticides Ltd., Alwayo ..	0.34	D.D.T. manufacture.
(3) M/s. Tata Chemicals Ltd., Mithapur	0.42	B.H.C. manufacture.
(4) M/s. Polychem Ltd., Bombay	1.50	Polystyrene manufacture.
(5) High Explosives Factory, Kirkee	0.12	
TOTAL	4.93	

All this benzene has to come from long distances from the coke-ovens attached to the steel mills. There is, therefore, an obvious added advantage if benzene and other aromatics are recovered from the two crackers in the Bombay region. The two crackers together might be able to produce about 13,000 tons of benzene per year, which would meet about half the requirements of the approved projects needing benzene in this region.

21. It is reported that the Nahorkatiya crudes are very rich in aromatics. It is also reported that benzene and toluene are present to the extent of 4.6% and 8.4% of the straight-run gasoline. The properties of some straight-run fractions from Nahorkatiya crudes are given below:—

Boiling range	Yield per cent	Density 20 P4	Content of hydro-carbons % wt.		
			Aromatic	Naphthenic	Paraffinic
28— 60	3.1	0.6640	0	22	78
60— 95	5.4	0.7350	12	54	34
95—122	4.7	0.7702	25	48	27
122—150	4.9	0.7950	43	31	26
150—200	9.7	0.8208	57	25	18
28—200	27.8	0.7700	34	35	31

It is very necessary to recover the aromatics which are valuable starting materials for the Organic Chemicals Industry and which would be in short supply. A scheme to recover the valuable aromatics from naphtha fractions would have to be thought of. The recovery of aromatics becomes necessary for two other reasons as well. Aromatics are not particularly good for naphtha-cracking or gasification process, because of their chemical stability due to absence of strain in their molecules. The presence of aromatics in kerosene makes the kerosene unsatisfactory for light purposes due to the formation of a smoky flame. It is understood that the Barauni

refinery envisages the production of 349,500 tons/year of motor gasoline consisting of the following fractions:—

	tons/year
(1) Straight-run naphtha	226,000
(2) Coker-naphtha	55,900
(3) Aromatic Extract	67,600
TOTAL	349,500

22. It would be seen from the analysis of straight-run naphthas that the 60°—95°C cut contains 12% aromatics, mostly benzene, and the 95°—122° C fractions contain 25% aromatics, mostly toluene. Xylenes would be present in the 122°—150°C cut. The recovery of these fractions will involve a preliminary separation of the desired cuts and subsequent extractions with solvents.

23. So far we have discussed the recovery of benzene that would become available as a by-product in the two crackers which are to be established in the Bombay region and the recovery of aromatics naturally present in the Nahorkatiya crudes. It is obvious that further steps would have to be taken to obtain additional quantities of aromatics from petroleum sources in the light of the anticipated demands by the end of the Fourth Plan period. The aromatics from petroleum sources are generally made from naphthenic rich fractions by isomerisation and dehydrogenation. The boiling range of the fraction is varied according to the product desired. For the maximum yield of aromatics choice of suitable fractions from an appropriate crude is essential. In the production of aromatics the steps involved are:—

- (a) Concentration of the naphthenes in the feed-stocks by pre-fractionation;
- (b) Conversion of hydro-carbons to aromatics;
- (c) Separation and purification of the aromatics.

There are a number of commercial processes for the catalytic reforming, like platforming, power-forming, houdri-forming, etc. As already indicated, steam-cracking of naphtha would be another source of aromatics (mainly benzene and toluene). The yield of aromatics in this process is small because the main object of a steam-cracker is production of basic olefines and di-olefines like ethylene, propylene, butadiene, etc.

24. The production pattern of the aromatics by the above mentioned methods does not conform to the demand pattern for the aromatics. In a catalytic reformat, for example, the production of toluene is much higher than benzene but, as is well-known, the demand for benzene is greater than for toluene. In order to rectify this imbalance, different processes such as the conversion of toluene, xylene and similar aromatics to benzene by de-alkylation with hydrogen are adopted. Similarly, catalytic light cycle stocks and

other refinery streams can give naphthalene by hydro-dealkylation process. Since none of the members of the Committee has expert knowledge and experience of modern processes and techniques adopted for the production and separation of aromatic from petroleum feed-stocks, the Committee feels it inappropriate to recommend any particular type of catalytic reforming. The Committee, however, feels that this problem deserves full consideration, since the production of aromatics from coal-tar would be inadequate to meet the country's requirements during the Third and the Fourth Five Year Plans. The Committee is of the definite opinion that it is essential to build up the necessary technical knowledge not only with regard to production, separation etc. of Aromatics from Petroleum Feed-stocks but also with regard to the diverse aspects of the petro-chemicals industry in the organisations such as the Development Wing, Department of Oil (Ministry of Steel, Mines and Fuel) and the Planning Commission which are closely associated with the development of the petro-chemical industry in the country. The only satisfactory way of building up the necessary technical knowledge in the concerned organisations would be by the technical officers of these organisations visiting the petro-chemicals units in the advanced countries. Unless this is done soon, it might become difficult to correctly assess the scheme submitted for the production of petro-chemicals and to exercise a check on the advice tendered by overseas consultations/experts which are essential for ensuring the proper growth and development of this major industry in India.

Utilisation of Assam Gas

25. It is understood that by about April, 1963, 38 million c. ft. of associated gases per day of the following composition would become available for use:—

Methane	..	..	..	..	..	..	90.40
Ethane	..	..	..	..	..	..	5.08
Propane	..	..	..	..	..	..	2.84
Iso-butane	..	..	..	..	..	..	0.47
N-butanes	..	..	..	..	..	..	0.66
Iso-pentane	}	..	..	..	..	..	0.55
N-pentane							
Hexenes							

26. It has been estimated that the LPG would yield the following quantities of hydro-carbons:—

	gals./day					
Propane	..	..	..	..	..	39,000
Iso-butane	..	..	..	..	..	12,000
N-butane	..	..	..	..	..	14,000
Pentane, etc.	..	..	..	..	..	9,000

27. Out of the 38 million c. ft. of gas per day, about 30.8 million c. ft. have already been ear-marked as per details given below.

There is, therefore, scope for expansion of the project under consideration as well as for inclusion of one or two new projects:—

Project	Likely date of completion	Gas requirement m.cft./day
(1) Fertilizer plant	1964	7.2
(2) Power plant	1963-64	9.2
(3) Cement factory	Under examination	3.2
(4) Gas distribution scheme for domestic and commercial purposes in Upper Assam	1962-63	6.2
(5) Carbon Black		5.0*
		30.8

*Gas requirement may be substantially higher.

28. Since the supply of natural gas is rather limited, a decision has already been taken to recover the LPG from the associated gases with a view to make it available for the manufacture of polyethylene and synthetic rubber (Cis-4-Polybutadiene). The LPG would be supplemented with the butanes/butylenes which might become available from the Gauhati and the Barauni refineries. This scheme for the manufacture of synthetic rubber is unlikely to be implemented as the N-butane/butylenes available in Assam would be inadequate to meet the requirements of the scheme.

29. Since the gases are required for many purposes, such as the manufacture of fertilizers and cement, generation of power etc., the facilities for the fractionation and separation of the constituents of the gases are likely to be set up by the Government of Assam with a view to making available the LPG for the manufacture of chemicals at reasonable prices. The Assam Government is taking steps to get a project report prepared by an overseas firm of consultants before proceeding further in the matter.

30. It is anticipated that in the second stage (i.e. by about 1968) 70 million c. ft. gas per day would become available. If this materialises, there would be a corresponding increase in the availability of LPG. There would be scope for expanding the capacity of some of the projects indicated above and also for the inclusion of new projects.

Price of Naphtha

31. The price at which naphtha would be made available for the manufacture of fertilizers, organic chemicals and related products would have a bearing not only on the utilization of the surplus naphtha but also on the cost of the manufactured article. It is understood that M/s. Burmah Shell Oil Distributing Co. have agreed to supply naphtha to M/s. F.A.C.T., Alwaye at Rs. 90.50 nP. per ton ex-Ernakulam installation. This price is subject to variation depending on the price of Bunker C. Oil at Persian Gulf on which the price calculation is based. In addition, delivery charges from the

Ernakulam installation to the F.A.C.T. storage tanks through M/s Burmah Shell's oil pipe-lines would be as follows:—

	Rs. per ton
Upto 25 metric tons per day	2.75
From 121 to 180 m. tons per day	2.40
From 181 m. tons and above per day	2.25

32. For the Trombay Fertilizer factory of the Fertilizers Corporation the price for raw naphtha would be about Rs. 73 per ton. This price has been fixed in relation to the c.i.f. value of Bunker C. Furnace Oil. It is necessary that the public sector refineries should also sell naphtha for the production of fertilizers at prices comparable with those for Trombay and F.A.C.T. It could be established by facts and figures that raw naphtha used for the production of fertilizers should be exempted from the payment of excise duty to ensure economic production of fertilizers. Light solvent naphtha (consisting of benzene and toluene) used as a raw material for the manufacture of chemicals is already being completely exempted from the excise duty and this should continue to be so in the interest of the Organic Chemicals Industry which is so vital for our economy. The total consumption of solvent naphtha would amount to approximately 84,000 tons by the end of the Third Five-Year Plan if circumstances favourable to such development are created in the country. It is, therefore, necessary that naphtha used in the production of all chemicals including nitrogenous fertilizers be exempted from payment of full excise duty as in the case of light solvent naphtha. The gains by way of corporate tax etc., accruing to Government by the establishment of new industries will more than compensate the loss of revenue from excise duty concessions. In this context, it may be recalled that the removal of duty on imported hydro-carbon oil used for chemical synthesis, as recommended by the Ayre Committee (1944), was chiefly responsible for the development of a flourishing petro-chemical industry in U.K.

Demand and Supply of Naphtha

33. In Chapter III, the estimated availability of surplus naphtha each year from 1960 to 1966 has been indicated. The greatest surplus of naphtha would occur in 1965 and it would go down in subsequent years as the naphtha-based production of petro-chemicals (and the products derived from them) and nitrogenous fertilizers would increase rapidly. Although the production of primary 'building materials', such as ethylene and propylene, from the naphtha crackers are expected to start towards the end of the Third Plan, the bulk of such production would be during the Fourth Plan period. The refining capacity is also expected to increase from about 10.8 million tons by the end of the Third Plan to about 20 million tons by the end of the Fourth Plan. It would, therefore, be appropriate to attempt an assessment of the demand and supply position of naphtha by 1970-71.

34. It has already been indicated in Chapter III that in 1966 the quantity of surplus naphtha would be about 899,000 tons. The availability of additional surplus naphtha during the Fourth Plan may be estimated at about 2 million tons (at the rate of 20% on 10 million of additional refining capacity) minus the increase of 10% per annum

over the 1966 figure of 1.22 million tons. (It has been estimated by the Oil Advisory Committee that the rate of increase in motor gasoline consumption during the Third Plan would be of the order of 7% per year). Thus the total surplus at the end of the Fourth Plan would be:—

	Surplus Naphtha
	tons
(1) Surplus at the end of the Third plan	899,000
(2) Additional surplus which would result during the Fourth Plan (2.00 m. tons—0.74 m. tons)	1,260,000
TOTAL	2,159,000

35. The demand for naphtha by the end of the Fourth Plan for manufacture of chemicals might be of the order of 2.15 million tons, as indicated below:—

	Tons
(1) Naphtha required for the manufacture of nitrogenous fertilizers in factories already licensed/approved as well as under consideration	396,000
(2) For production of town gas for the city of Bombay (approved project)	95,000
(3) For captive steam-cracker of M/s. Union Carbide (licensed) ..	60,000*
(4) For four steam-crackers each having a capacity of the order of 200,000 tons naphtha throughput	800,000**
(5) Special naphtha-cracking unit for production of C ₄ s.	300,000***
(6) For production of nitrogenous fertilizers during the Fourth Plan ..	500,000***
TOTAL	2,151,000

*The firm's request for permission to increase the capacity to 85,000 tons/year is under consideration. If M/s. Standard Vacuum Refining Co. of India Ltd., Bombay are permitted to put up a steam-cracker of 200,000 tons/year throughput, M/s. Union Carbide may reconsider their decision to put up their own cracker.

**Includes M/s. Stanvac's licensed capacity of 100,000 tons/year steam-cracker.

***The production of nitrogenous fertilisers in terms of nitrogen is expected to increase from 1 million tons in 1965-66 to 2 million tons in 1970-71. Out of the additional production of 1 million tons during the Fourth Plan it is assumed that about 50% would be based on naphtha.

36. The demand and supply of naphtha by the end of the Fourth Plan appear to be very close to each other. If the rate of increase in motor gasoline consumption increases at a faster rate than 10% per annum assumed during the Fourth Plan and/or more than 50% of the additional production of nitrogenous fertilizers during the Fourth Plan is based on naphtha, there would be a deficit and this would have to be bridged, as discussed earlier in this Chapter, by either imports of naphtha or by increasing the refining capacity in the country beyond 20 million tons.

CHAPTER VI

Estimated current availability of organic chemicals and related products, the extent to which the demand for these products would have to be based on petroleum and non-petroleum feed-stocks, estimates regarding investment, value of production etc.

1. In this chapter an attempt has been made to estimate:—

- (a) the current availability in the country of the more important organic chemicals and other related/derived products and the value of estimated demand for these products by 1965-66 and 1970-71;
- (b) the extent to which the demand for feed-stocks as well as the derived products would be met from petroleum and non-petroleum sources by the end of Third and Fourth Plans; and
- (c) the investment on plant and equipment and the foreign exchange component of the investment.

Current availability of the more important organic chemicals and other related/derived products and the value of estimated demand for these products by 1965-66 and 1970-71.

2. Current (1960) availability referred to at (a) above has been computed solely on the basis of indigenous production plus imports, direct as well as indirect (as derivatives) as there is hardly any export at present of the items under consideration. From the data on the quantity of imported derived products, the corresponding quantities of primary products have been worked out. The foreign exchange spent on direct and indirect imports (as derivatives) in 1960 works out to approximately Rs. 30 crores. The estimated demand of organic chemicals and derived products excluding basics such as Benzene, Naphthalene, Methyl Alcohol and Ethyl Alcohol by the end of the Third Five Year Plan works out to about 400,000 tons valued at approximately Rs. 122 crores at current c.i.f. prices. Corresponding figures by the end of Fourth Plan work out to about 960,000 tons, valued at about Rs. 260 crores. Detailed information would be found in Statement I.

Extent to which the demand for feed-stocks and derived products would be met from petroleum and non-petroleum sources by the end of the Third and Fourth Plans.

3. From Table II it would be evident that while by the end of the Third Plan, products equivalent to about 198,000 tons of Carbon would be derived from non-petroleum sources such as Fermentation Alcohol, Coke Oven by-products and Calcium Carbide, products equivalent to about 175,000 tons of Carbon would be derived from petroleum sources including Natural Gas. A similar assessment (Table III) indicates that by the end of Fourth Plan products equivalent to 293,000 tons of Carbon may be derived from non-petroleum sources; while products equivalent to 542,000 tons may be derived from petroleum sources. It would thus be evident that petroleum

and non-petroleum products (Fermentation Alcohol, Coke Oven by-products and Calcium Carbide) are still primarily complementary sources of chemicals. While some capacity for non-petroleum starting raw materials has already been established and substantial further capacity is in various stages of implementation, capacity in respect of basic petro-chemical feed-stocks is yet to be established.

Investment on plant and equipment and the foreign exchange component of the investment.

4. The estimate of investment indicated in Table IV is intended to serve only to indicate the order of investment involved. Capacity in respect of basic petro-chemical feed-stocks is yet to be established in the country and many of the major petro-chemical projects require 2/3 years for completion and therefore some of the investments envisaged under the 3rd Plan would inevitably spill over into the Fourth Five Year Plan. From the experience gained from the implementation of the Second Five Year Plan it is evident that part of the investment necessary for fulfilling the targets under the 4th Plan would have to be met during the later part of 3rd Plan itself. It has been, therefore, felt that no useful purpose would be served by analysing the 3rd Plan targets only for the purpose of assessing the investment. It has been considered both realistic and desirable to take the estimated demand for various products by the end of the 4th Plan for the purpose of assessing the order of investment in the field of petro-chemicals.

5. In preparing these estimates data available from a number of sources have been taken into consideration. Amongst these may be mentioned :—

1. Industrial Chemicals by Feith, Keyes and Clark (John Wiley and Sons Inc. 1960);
2. Petroleum Refiner (July, Vol. 40, pp. 220-243);
3. Chemical Week (July 16, 1961, pp. 31-35);
4. Certain estimates made available to the Committee by those who had discussions with the Committee; and
5. Data relating to individual products available in the Development Wing.

6. While the investment on plant and equipment alone for the production of basic feed-stocks amounts to approximately Rs. 177 crores, the corresponding investment in respect of derived products amounts to about Rs. 200 crores, making a total of Rs. 317 crores. The foreign exchange component in respect of plant and equipment for the basics would be about Rs. 64 crores and about Rs. 101 crores for the derived products; thus the total foreign exchange component would be about Rs. 165 crores. The above estimates are in respect of basic feed-stocks and the more important derived products mentioned in Table IV. If other derived products and also the other facilities which would have to be brought into existence before a product could reach consumers is also included, the investment would be very much higher but the foreign exchange component for such facilities would be rather small. It is likely that the total investment starting from the basic feed-stocks to ultimate distribution of commercially saleable diverse products would be of the order of Rs. 500/600 crores.

7. The above estimates relate to organic chemicals and related products and do not take into consideration the investment necessary for the production of Nitrogenous Fertilizers based on petroleum feed-stocks.

8. Against a total investment on plant and equipment of the order of Rs. 317 crores in respect of basic feed-stocks and the more important derived products, the value of the organic chemicals and associated products produced would be about Rs. 260 crores. This underlines the fact that the Petro-chemical Industry is a capital intensive industry.

9. There is considerable enthusiasm on the part of overseas firms to invest in the field of Petro-chemicals Industry in this country and it might be reasonably anticipated that a substantial portion of the foreign exchange required for the import of plant and equipment could be obtained as overseas investment. It is a moot point whether by restricting investments in these fields, it will be possible to automatically secure inflow of resources into other fields, admittedly of higher priority.



सत्यमेव जयते

1. PRODUCTION IMPORTS AND CURRENT USAGE OF ORGANIC CHEMICALS WITH ESTIMATES OF DEMAND IN 1965-66 & 1970-71
(Qty. in Tons)
(Value in Rs. lakhs)

Sl. No.	Item	Current availability and usage 1960-61						Estimated demand for 1965-66		Estimated demand for 1970-71	
		Direct Derivatives Imported		Equiva- Estimated		Qty. in Tons	Value of total foreign exchange spent in 1960 columns on products 3, 4 & 6	Qty. (tons)	Value (Rs. lakhs) at current CIF values	Qty. (tons)	Value (Rs. lakhs) at current CIF values
		Produce- tion (tons)	Import (tons)	Item	Qty. (tons)						
1	2	3	4	5	6	7	8	9	10	11	12
1.	Ethyl Alcohol	..	70,000	..	..	..	..	200,000	600(1)	290,000	870(1)
2.	Benzene	..	16,000	..	..	..	..	80,000	480	170,000	1,020
3.	Naphthalene	..	..	..	..	..	15,000	20,000	120	40,000	240
4.	Carbon Black	..	..	..	..	..	..	35,000	350	70,000	700
5.	Phthalic Anhydride	..	..	..	..	..	2,500	65	18,000	390	850
6.	Methyl alcohol	..	Negligible	600	..	..	..	25,000	100(2)	70,000	280(2)
7.	Chlorohydro Carbons (includes freons)	Nil	..	..	..	..	..	..	..	..	..
8.	Acetic Acid	..	3,300	1,900	..	..	..	29,000	348	57,000	684

Phthalates
Anthraquinones
Formaldehyde
Hexamine
Pentaerythritol
Resins, Rongalite etc.
Trichlorethylene
Perchloroethylene
Carbon Tetrachloride
Freons
Others
Acetates
Cell Acetate
Others.

9.	Ethylene Oxide	..	..	..	n.a.	{ E. glycol Syndets, Terylene Esters, amines etc.	200 n.a.	1,000	90	5,000	150	10,000	300
10.	Polypropylene	..	..	..	—	—	—	—	—	6,000	300	20,000	1,000
11.	Polyethylene	..	..	..	4,200	—	—	4,500	10	36,000	1,260	115,000	4,000
12.	Vinyls (includes Polyvinyl acetate)	..	..	..	3,150	—	—	4,800	90	32,000	960	83,000	2,490
13.	Styrene Monomer	..	..	..	—	—	n.a.	—	—	—	—	—	—
14.	Polystyrene	..	..	..	—	—	deg.	8,000	160	33,000	725	71,000 ⁽²⁾	1,562 ⁽²⁾
15.	Phenol	..	..	..	3,600	25	4,000	3,700	—	20,000	160 ⁽³⁾	50,000	400 ⁽³⁾
					2,060	{ Resins & moulding powder Salicylic acid Others	300* 400 n.a.	3,000	60	18,000	400	43,000	946
16.	Dodecyl Benzene	..	..	..	—	n.a.	{ Syndets Lindane	1,000* 4,500	20	8,000	160	24,000	480
17.	B.H.C.	..	..	..	3,900	—	n.a.	15,000	5	15,000	375	25,000	625
18.	Aniline	..	..	..	—	—	{ Dyes and Interme- diates	1,500*	45	4,000	120	10,000	300
19.	D.D.T.	..	..	..	2,800	22,800	{ Acetanilide Rubber accelerators	n.a.	930	6,000	240	9,000	360
20.	Polymethyl Methacrylate	..	..	..	—	—	{ Sheets rods etc. Other fabricated products	300 n.a.	40	4,000	240	8,000	480
21.	Cellulose Plastics	..	..	..	—	1,600	{ Sheets Rods & Tubes Nitrate Sheets etc. Raw film	3,000 1,000 n.a.	150	7,000	310	10,000	400
22.	Acetone	..	..	..	1,200	50	{ Diacetone alcohol Others such as IPA, MIBE, etc.	3,000	30	9,500	96	18,000	180
23.	Synthetic Elastomers	..	..	..	—	*4,000	{ Natural Rubber Nylon-moulding Powder, nylon yarn etc.	20,000* n.a.	700 100	70,000 12,000	2,310 960	170,000 28,000	5,610 2,240
24.	Caprolactum (Nylons)	..	..	..	—	—		1,000					
25.	Ethylene Dichloride	..	..	..	—	675	{ Fumigants T.E.L.	1,500* n.a.	30	9,000		13,500	135

*Only a rough approximation
(1) at Indian prices
(2) bulk shipment rates
(3) Extra to styrene

II. PRODUCTION FROM PETROLEUM AND NON-PETROLEUM SOURCES BY 1965-66

(Figures in Tons)

Sl. No.	Item	Estima- ted demand	Anticipated produc- tion from non-petro- leum sources		Gap to be met by production from Petroleum Sources					Remarks
			Quantity	Carbon content	Quantity	Carbon content	Feed-stock requirements		Quantity	
							Types			
1	2	3	4	5	6	7	8	9	10	
	Carbon Black	..	10,000	10,000	25,000	25,000	Gas or heavy aromatic oils	60,000		
BASICS										
1.	Methanol	..	—	—	25,000	10,000	All types	25,000		
2.	Ethyl alcohol	..	200,000	102,000	—	—	—	—		
3.	Acetylene	..	29,000	27,000	50,000	43,000	Naphtha/nat. gas.	200,000		
4.	Ethylene	..	25,000(1)	—	18,000	16,000	Naphtha/nat. gas.	200,000		
5.	Propylene	..	2,000(1)	—	—	—	—	—		
			(Acetone)							
6.	Butadiene	..	22,000(1)	—	33,000	30,000	Butanes }	80,000		
7.	Isobutylene	..	—	—	13,000	11,000	Butanes }	—		
8.	Benzene	..	50,000	46,000	30,000	27,000	Naphthenic distillates	—		
9.	Xylenes (pure)	..	—	—	15,000	14,000	Naphthenic distillates	—	includes O-xylene for meeting deficit in naphthalene	
10.	Naphthalene	..	14,000	13,000	as o-xylene	—	—	—		
TOTAL carbon content of above			198,000	175,000						
DERIVED PRODUCTS										
11.	Polyethylene	..	8,500	—	27,500	—	Ethylene	31,000		
12.	Styrene	..	25,000	—	2,000	—	Ethyl. alcohol	18,000		
							Ethylene	3,000		
13.	Polypropylene	..	—	—	6,000	—	Benzene	33,000		
14.	Vinyl Resins (PVC & PVA)	32,000	22,000	—	10,000	—	Propylene	6,500		
15.	Methacrylate and acrylates	4,000	From acetone, methanol etc.	—	—	—	Ethylene	6,000	HCN requirement	

HCN requirement is not included in the hope that production may be from methanol via formamide

16.	Cellulose acetate etc. ..	7,000	From acetic acid	—	—	36,000	
17.	Synthetic Elastomers	70,000	30,000	40,000	—	12,000	
18.	Chlorohydro-carbon ..	14,000	8,000	6,000	—		Direct produc- tion from me- thane gas may not be established.
19.	Acetic Acid ..	29,000	29,000	—	—	29,000	
20.	Ethylene Oxide ..	5,000	—	5,000	—	5,000	
21.	Ethylene Dichloride ..	9,000	3,000	6,000	—	2,000	
22.	Acetone ..	9,500	2,500	7,000	—	6,000	
23.	Dodecene and related low Polymers	6,000	—	6,000	—	7,500	Refers to Dodecene and not DDB.
24.	Aniline ..	4,000	From benzene	—	—		
25.	B.H.C. ..	15,000	From benzene	—	—		
26.	D.D.T. ..	6,000	From benzene and ethyl alcohol	—	—		
27.	Phenol ..	19,500	From benzene	—	—		
28.	Caprolactum ..	12,000	From Phenol or Benzene	—	—		
29.	Phthalic anhydride ..	13,000	From Naphthalene/O-xylene	—	—		
30.	Nitrogenous Fertilisers (as N)	10,00,000					

(1) Carbon equivalent included in ethyl alcohol.

III. PRODUCTION FROM PETROLEUM & NON-PETROLEUM SOURCES BY 1970-71

(Figures in Tons)

Sl. No.	Item	Estimated demand	Anticipated production from non-petroleum sources		Gap to be met by production from Petroleum Sources					Remarks
			Quantity	Carbon content	Quantity	Carbon content	Feed-stock requirements			
							Type	Quantity		
1	2	3	4	5	6	7	8	9	10	
	<i>Carbon Black</i>	..	70,000	20,000	50,000	50,000	Gas or heavy Oils.	120,000		
	<i>BASICS</i>									
1.	Methanol	..	70,000	—	70,000	27,000	All types	70,000		
2.	Ethyl alcohol	..	290,000	148,000	—	—	—	—		
3.	Acetylene	..	60,000	37,000	20,000	18,000	Nat. gas or naphtha	675,000	(1) possibly a further 500 could be expected from coke oven gas.	
4.	Ethylene	..	190,000	—	165,000	143,000	Do.	—		
5.	Propylene	..	61,000	—	58,000	50,000	Do.	Co-product		
6.	Butadiene	..	185,000	—	163,000	14,000	Butanes	300,000		
7.	Isobutylene	..	—	—	—	—	—	—		
8.	Benzene	..	170,000	69,000	95,000	82,000	Naphthenic distillates	—		
9.	Xylene (Pure)	..	40,000	19,000	19,000	—	Do.	—		
10.	Naphthalene	..	20,000	—	30,000	27,000	—	—		
	TOTAL of Carbon	..	..	293,000	542,000	542,000				
	<i>DERIVED PRODUCTS</i>									
11.	Polyethylene	..	115,000	10,000	105,000	—	Ethylene	115,000		
12.	Styrene	..	71,000	30,000	41,000	—	Ethylene	16,000		
13.	Polypropylene	..	20,000	—	20,000	—	Propylene	22,000		
14.	Vinyl Resins (PVC & PVA)	..	83,000	33,000	50,000	—	Acetylene	—		
							Ethylene	—		
15.	Methacrylate and Acrylate	..	8,000	From acetone, methanol etc.	—	—	—	—	Quantity from petroleum sources only.	
16.	Cellulose Acetate etc.	..	10,000	From Acetic acid	—	—	—	—	Alternate production isobutylene.	

Quantity from petroleum sources only.
Alternate production isobutylene.

17. Synthetic Elastomers	170,000	30,000	140,000	Butadiene } isobutylene }	16,800	Quantity of each may vary & pro- pylene may also be used for isoprene in place of isobu- tylene. Additional direct production from ethyplene.
18. Chlorohydro carbons	25,000	12,000	13,000	Methanol or methane Acetylene Ethylyene or Acetylene Ethylyene Propylene Propylene		
19. Acetic Acid	57,000	45,000	12,000			
20. Ethylene Oxide	10,000	—	10,000			10,000
21. Ethylene Dichloride	13,500	4,500	19,000			3,000
22. Acetone	18,000	2,500	15,500			16,000
23. Dodecene & related low poly- mers	18,000	—	18,000			23,000
24. Aniline	1,000	From benzene				
25. B.H.C.	25,000	From benzene				
26. D.D.T.	9,000	From benzene & ethyl alcohol				
27. Phenol	43,000	From benzene				
28. Caprolactum	28,000	From phenol or Benzene				
29. Phthalic Anhydride	28,500	From naphthalene or O-xylene.				
30. Nitrogenous fertilisers	2 million tons					

ESTIMATES OF INVESTMENTS

Item	Estimated demand for 1970-71	Capacity to be developed (excludes units installed or nearing completion)	Unit capacity tons/day	Approx. investment on plant unit (Rs. Lakhs)	No. of units required	Total estimated fixed investment on plant and equipment	Possible foreign exchange requirements (Rs. Lakhs)	Remarks
1	2	3	4	5	6	7	8	9
Nitrogenous Fertilizers (as N)								
Carbon Black	.. .. .	70,000	56,000	30 to 40	200	1,200	360	
BASIC FEED-STOCK UNIT								
Naphtha Cracker for Ethylene and Propylene with by-product	190,000	165,000	600 tons	900	4	3,600	2,200	
Butadiene and Benzene	60,000	56,000 { 25,000 } 20,000						
Dehydrogenation/Extraction Plants for Butadiene and Isobutylene	185,000	140,000	100	350	4	1,400	840	
Reformer/Extraction Plants for Benzene/Xylenes	210,000	114,000	60 to 100	1,000	3	3,000	1,800	
High temp. Pyrolysis units for Acetylene with or without Ethylene.	60,000	20,000	30	300	2	600	360	Could be linked to methanol or ammonia units.
Isoprene	.. .. .	33,000	100	500	1	500	300	From Isobutylene or Propylene.
Methanol	70,000	7,000	60	200	3	600	360	
Ethyl Alcohol	290,000	130,000	12	15	30	450	45	
Calcium carbide/Acetylene	40,000	21,000	10	60	6	360	180	
Coke oven Byproduct Plant	.. .. .	.. .. .	.. .. .	.. .. .	.. .. .	.. .. .	.. .. .	included as essential component of coke oven plant.

CHAPTER VII

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

1. The demand for organic chemicals, synthetic rubber, plastics, pesticides, detergents etc. is rising very rapidly in the country. The three chief raw materials for the Organic Chemicals Industry, viz. petroleum and its products, coal-tar products, vegetable matter and fermentation products thereof would become available shortly for the first time in the country in substantial quantities. The Organic Chemicals Industry, which can be said to have just started in the country, is therefore on the threshold of major developments and one may expect a spectacular growth and development of this industry during the next decade. (Chap. I, para 2).

2. While the raw materials from carbonisation of coal are aromatic compounds, those from petroleum are largely aliphatic compounds. Since modern processes enable compounds of both types to be obtained from either, coal and petroleum may be regarded as complementary as well as supplementary sources of chemicals. Both are, therefore, necessary for the modern Organic Chemicals Industry. (Chap. IV, para 3).

3. In the industrially advanced countries the demand forecasts for different organic chemicals and other products are worked out on the basis of projecting the consumption rates in relation to current levels and the growth of income and their distribution in the country. The studies would also cover patterns and shifts in consumption expenditure. Such an approach is not feasible at the present stage in India, because the Organic Chemicals Industry is still in its infancy. (Chap. IV, para 9).

4. Further in a planned economy dependent on heavy imports for development, restraints on consumption are expected to operate. The Committee is not in a position to make assumptions about such restraints. (Chap. IV, para 9).

5. The restrictive factors acting as a brake on consumption would have been largely overcome by the end of the Third Plan and thereafter production could be expected to expand freely in response to demand. (Chap. IV, para 9).

6. Targets for more important products under the Third as well as Fourth Five-Year Plan have been worked out taking into consideration estimated domestic demand, minimum economic size of manufacturing units, export potentialities, etc. (Chap. IV, para 10).

7. Some of the more important products the production of which will have to be taken up first have been listed and targets of production for them under the Third and Fourth Plans have been suggested. (Chap. IV, para 10).

8. The Committee is of the view that if there are no restraints on consumption and investments nor abnormal price increases, the demand estimates worked out for the end of the Third and the Fourth

Plans would definitely be reached. It is noted that the targets proposed for 1965-66 in the Report on the Third Plan for some of these products are lower than those suggested by the Development Council. The report, however, states that the revision of these targets is open to consideration in the Third Plan period. (Chap. IV, para 11).

9. In order to ensure the production of adequate quantities of organic chemicals and other products, it would be necessary to ensure that the following primary raw materials which would be used as feed-stocks are made available to the extent indicated below for the Organic Chemicals Industry. (Chap. IV, para 12).

						1965-66	1970-71
						Tons	Tons
(1) Methanol						25,000	6000,0
(2) Ethyl Alcohol						200,000	290,000
(3) Ethylene						50,000	165,000
(4) Propylene						20,000	70,000
(5) N-Butane/N-Butylenes						60,000/45,000	160,000/120,000
(6) Isobutylenes						13,000	67,500
(7) Acetylene						24,000	59,000
(8) Benzene						80,000	180,000
(9) Naphthalene						20,000	40,000

10. Production of methanol and ethylene could be organised either from coke-oven gases or petroleum feed-stocks. Propylene, N-butane/N-butylenes, Iso-butane/Iso-butylene would have to be based on petroleum feed-stocks. (Chap. IV, para 13).

11. The entire requirement of ethyl-alcohol would be obtained by the fermentation of molasses and it would not be necessary to produce ethyl-alcohol based on petroleum products. (Chap. IV, para 14).

12. Part of the requirements of benzene would be met from coal-tar source, the balance being met from petroleum source. (Chap. IV, para 15).

13. Almost the entire quantity of acetylene needed by the end of the Third Plan is assumed to be met from calcium carbide. During the Fourth Plan there might be some production of acetylene from petroleum sources depending on its economics. (Chap. IV, para 17).

14. The demands for Cis-4-Polybutadiene, Poly-isoprene and butyl rubbers are likely to be interchanged, and this fact would have to be taken into account while creating capacity for synthetic rubber. The position would be somewhat similar in the case of major plastics, namely PVC, polyethylene and polystyrene. (Chap. IV, para. 18).

15. In the past the demand for benzene for the Organic Chemicals Industry was small but during the next few years the demand is expected to increase very rapidly which would not be met by the benzene recovered from coal carbonisation units. This is so because coal carbonisation is linked mainly to steel production and the rate of increase in the production of organic chemicals would be much faster as compared to the rate of increase in steel production.

Therefore, the gap between demand and supply of benzene would have to be bridged by the production of benzene from petroleum source. (Chap. IV, paras 28 and 29).

16. Aromatics are generally made from petroleum source by catalytic reforming of naphthenic rich fractions. Several commercial catalytic-forming processes are available and the process best-suited to meet the country's requirements will have to be chosen. (Chap. IV, para 30).

17. Toluene content in the reformat is higher than the benzene content, but the demand for benzene is greater than for toluene. By selection of proper fractions it would be possible to rectify this imbalance. (Chap. IV, para 30).

18. The crudes refined at present in India are imported from Middle East and these contain comparatively small quantity of naphthenes since these are mixed base. These crudes, therefore, are not suitable for production of aromatics. (Chap. IV, para 31).

19. We would have a very good source of crude for the manufacture of aromatics in the Nahorkatiya crudes which are very rich in aromatics as well as naphthenic hydro-carbons. Since there is likely to be a shortage of benzene in the country, it is necessary that the indigenous crudes are suitably processed for the recovery of aromatics. (Chap. IV, paras 31 and 32).

20. While the light gasoline fraction of Cambay crude is reported to contain 18.2% naphthenes and 4.2% aromatics, the light fraction of Ankleshwar crude is reported to contain 32.2% naphthenes and 10% aromatics. These crudes, particularly the one from Ankleshwar, appear to be suitable for the production of aromatics. (Chap. IV, para 33).

21. Since the demand for benzene for the projects already sanctioned in the Western region of the country is about 20,000 tons/year and the naphtha-cracking units (steam-crackers) in that region would only meet about half of this requirement, there is need for additional benzene which can be met either by expanding the capacity of the naphtha-crackers already sanctioned and/or by catalytic reforming and isolation of aromatics. In this context the production of aromatics from Ankleshwar crude in the new refinery would deserve careful consideration. (Chap. IV, para 33).

22. Catalytic reformers and naphtha-crackers should, as far as possible, be set up in conjunction with refineries. There would be certain advantages in a refinery itself setting-up a catalytic reformer because the non-aromatic fractions of a reformat could be used with advantage by a refinery for gasoline blending and this would influence the economics of the aromatics plant as well as the refinery. Similar considerations would hold good in respect of steam-crackers also. Under exceptional circumstances, however, a steam-cracker may have to be set up independently. (Chap. IV, para 34).

23. Since the plants for the manufacture of aromatics are capital intensive, it is essential to ensure that the units are of economic size because it is important that the products are made available to the

other industrial consumers at prices comparable with world prices for these commodities or in competition with supplies from steel plants in the country. (Chap. IV, para 34).

24. In addition to methane, propane, butanes and pentanes, considerable quantities of hydrogen would become available as a by-product in the catalytic reformers and these would have to be utilized to the best advantage. (Chap. IV, para 34).

25. Toluene obtained from coal carbonisation units and the catalytic reformers would be far in excess of internal requirements and its disposal would pose a problem. A solution to this problem can be found either by adding it to motor gasoline as high octane component or by its conversion to phenol as well as to benzene by dealkylation with hydrogen. Exports, if feasible, will also provide another outlet. (Chap. IV, para 37).

26. While there would be a good demand for O-xylene for conversion to phthalic-anhydride—there might even be shortage of O-xylene—the disposal of m-xylene would be a serious problem. It may become necessary to adopt processes for the isomerisation of m-xylene to O-xylene and p-xylene mixture and thus reduce the magnitude of the problem. (Chap. IV, para 38).

27. The amount of naphthalene which would be recovered from coal carbonisation units would be inadequate to meet the demand for it in the country. The production of naphthalene from petroleum source is on its way for the first time even in U.S.A. Therefore, the gap between demand and supply may have to be bridged by the use of an alternative starting material viz. O-xylene for the production of phthalic-anhydride. (Chap. IV, para 39).

28. Since the demand for ethylene and propylene would not be met by the two steam-crackers which have already been approved in the Bombay region, it is evident that further step-up of steam-cracking facilities would be needed even during the Third Plan vis-a-vis the demand forecasts for ethylene and propylene. (Chap. IV, para 41).

29. The production of indigenous raw rubber in the plantations in South India has not been able to keep pace with the rapidly increasing demands of the Rubber-goods Manufacturing Industry. The demand for all varieties of rubber, which was of the order of 58,000 tons in 1960, is expected to rise to 141,000 tons in 1965 and to 282,000 tons in 1970. The production of natural rubber is expected to increase from the current level of about 25,000 tons to about 40,000 tons by 1965 and about 55,000 tons by 1970. It is, therefore, necessary to fill the gap between supply and demand by undertaking the production of synthetic rubber on a large scale. In view of the limited availability of natural rubber, it will be necessary to undertake the manufacture of those varieties of synthetic rubbers which would need the least amount of natural rubber for compounding. On this score the choice would have to be in favour of manufacturing two stereo-specific rubbers, viz. Cis-4-polybutadiene and Cis-polyisoprene. The manufacture of butyl rubber deserves further

consideration. There would be no need for creating additional capacity for SBR type of synthetic rubber, since it cannot be used alone or in substantial quantities in admixture with natural rubber in the manufacture of giant tyres which would continue to constitute the bulk of the automobile tyres produced in the country for a fairly long time to come. (Chap. IV, paras 42 and 46).

30. The most profitable uses of surplus naphtha would be as a raw material for production of materials that would save maximum foreign exchange. Such materials are nitrogenous fertilizers, petrochemicals and town gas for substitution of kerosene as a domestic fuel. The alternative suggestion is to use naphtha temporarily in admixture with gas oil. However, before marketing any such blend some administrative problems would have to be solved. (Chap. V, para 3).

31. Use of naphtha for nitrogenous fertilizers production would save foreign exchange equivalent to about ten times its value. Similarly, when naphtha is used for production of organic chemicals, plastics etc., the value of the material produced per ton of naphtha would vary from three to seven times the cost of naphtha depending on the nature of the ultimate product. (Chap. V, para 4).

32. In case adequate quantities of surplus naphtha from the indigenous sources are not available for the manufacture of nitrogenous fertilizers, organic chemicals and other products, the shortfall would have to be made good by imports till the indigenous supply catches up with demand because it would cost less foreign exchange to import naphtha than the import of finished products derived from it. In this connection, it would be advantageous to import suitable crudes and make available naphtha for the chemical industry after refining. The Committee is of the view that Government may proceed on the basis that naphtha will be available either from indigenous sources or, if necessary, for a very short period by imports to feed such schemes as may be considered important enough for licence under the Industries Act on import-saving or foreign exchange earning considerations. It is also recommended that projects which have already been approved may be processed on this basis. (Chap. V, para 9).

33. With a view to ensure balanced development of different parts of the country and also to minimize the transport of chemicals and other finished products which would be needed in the various regions of the country, it would be necessary to set up naphtha-cracking units in the different regions. Since these crackers would have to draw naphtha from the refineries, it stands to reason that while setting up new refineries the natural supply area also would have to be taken into consideration. In this context, it would be necessary to set up a refinery in South India. This would obviate the need for transport of naphtha from Bombay to F.A.C.T., Alwaye and also would help in setting up petro-chemical industry in South India to meet the requirements of that region. (Chap. V, para 12).

34. Plants for the manufacture of aromatics, olefins and organic chemicals, plastics, synthetic rubber, detergents, etc. are capital intensive and do not lend themselves to small-scale operations. The

setting up of such units can be justified only when large volume operations are feasible. (Chap. V, para 13).

35. Decision regarding the location and size of unit should be based on economic considerations. While encouraging the setting up of crackers as well as other units during the Third and Fourth Five-Year Plans, an attempt must be made to ensure that the units set up are of economic size so that the cost of production is comparable with that in other countries. Under these circumstances, the Organic Chemicals Industry in the country would have a firm footing and its products would offer considerable scope for organising exports at least to neighbouring countries. (Chap. V, para 13).

36. It is recommended that steps be taken for setting up four steam-cracking units in the Western, Eastern and Southern zones of the country to meet the requirements of ethylene, propylene; butylenes, butadiene, benzene, etc. From economic considerations it is essential to establish the steam-cracking units near refineries. The first steam-cracking unit should be established near the Bombay refineries; the second near the Barauni refinery; the third near the Gujrat refinery and the fourth near a refinery to be set up in South India. (Chap. V, para 15).

37. By the end of the Third Plan while there would be a surplus of motor gasoline, there would be deficits in all the other items, particularly the middle distillates. In order to reducing/removing these deficits it is recommended that additional refining capacity should be set up in South India. This step, in addition to removing the deficits, would also yield additional naphtha for the Petro-chemical Industry. (Chap. V, para 15).

38. Utilizing the starting materials obtained from the steam-crackers, petro-chemical complexes involving the manufacture of diverse products should be undertaken to fulfil the estimated demand indicated by the end of the Third and the Fourth Plan periods. (Chap. V, para 16).

39. Depending upon the products to be included for production in these petro-chemical complexes, it would be necessary to decide whether steam-crackers would be of the low severity type or of the high-severity type. (Chap. V, para 17).

40. The amount of C_4 s available is rather limited and these should be utilized for the production of synthetic rubbers which are of strategic importance. C_4 s should not be used as fuel in LPG. In order to augment the C_4 s it may be necessary to set up a special naphtha-cracking unit somewhere in North India. (Chap. V para 18).

41. The Committee is of the definite opinion that it is essential to build up the necessary technical knowledge not only with regard to production, separation, etc. of aromatics from petroleum feed-stocks but also with regard to diverse aspects of the Petro-chemical Industry in the organisations such as the Development Wing, the Department of Oil (Ministry of Steel, Mines & Fuel) and the Planning Commission, which are closely associated with the development

of the Petro-chemical Industry in the country. The only satisfactory way of building up the necessary technical knowledge in the concerned organisation would be by the technical officers of these organisations visiting the petro-chemical units in the advanced countries. Unless this is done soon, it might be difficult to correctly assess the schemes submitted for the production of petro-chemicals and to exercise a check on the advice tendered by overseas consultants/experts, which are essential for ensuring the proper growth and development of this major industry in India. (Chap. V, para 24).

42. It is necessary that naphtha used in the production of all chemicals and other products including nitrogenous fertilizers be exempted from payment of import and excise duty. In this context, it may be recalled that the removal of duty on imported hydro-carbon oil used for chemical synthesis, as recommended by the Ayre Committee (1944), was chiefly responsible for the development of a flourishing Petro-chemical Industry in U.K. The gains by way of corporate tax etc. accruing to Government by the establishment of new industries will more than compensate the loss of revenue from excise duty concessions. (Chap. V, para 32).

43. The demand and supply of naphtha for the Chemical Industry by the end of the Fourth Plan appears to be very close to each other (about 2.15 million tons). If the rate of increase in motor gasoline consumption increases at a faster rate than 10% per annum during the Fourth Plan and/or more than 50% of the additional production of nitrogenous fertilizers during the Fourth Plan is based on naphtha, there would be a deficit which could be bridged by increasing the refining capacity in the country beyond 20 million tons. (Chap. V, para 36).

44. The foreign exchange spent on direct and indirect imports of organic chemicals and related products in 1960 works out to approximately Rs. 30 crores. The estimated demand of organic chemicals and derived products excluding basics such as benzene, naphthalene, methyl-alcohol and ethyl-alcohol by the end of the Third Five-Year Plan would be about 400,000 tons, valued at approximately Rs. 122 crores at current c.i.f. prices. Corresponding figures by the end of the Fourth Plan would be 960,000 tons, valued at Rs. 260 crores. (Chap. VI, para 2).

45. While by the end of the Third Plan products equivalent to about 198,000 tons of carbon would be derived from non-petroleum sources, products equivalent to about 175,000 tons of carbon would be derived from petroleum sources including natural gas. A similar assessment indicates that by the end of the Fourth Plan products equivalent to 293,000 tons of carbon may be derived from non-petroleum sources while products equivalent to 542,000 tons may be derived from petroleum sources. (Chap. VI, para 3).

46. While investment on plant and equipment alone for the production of basic feed-stocks amounts to approximately Rs. 117 crores, the corresponding investment in respect of derived products amounts to about Rs. 200 crores making a total of Rs. 317 crores. The foreign exchange component in respect of plant and equipment for basics would be about Rs. 64 crores and about Rs. 101 crores for the

derived products; thus the total foreign exchange component would be about Rs. 165 crores. It is likely that the total investment, starting from the basic feed-stocks to the ultimate distribution of commercially saleable products, would be of the order of Rs. 500 to 600 crores. (Chap. VI, para 6).

47. There is considerable enthusiasm on the part of overseas firms to invest in the field of Petro-chemical Industry in the country and it might be reasonably anticipated that a substantial portion of the foreign exchange required for the import of plant and equipment could be obtained as overseas investment. (Chap. VI, para 9).

ACKNOWLEDGEMENT

The Committee wishes to place on record its thanks to all those who assisted in its work and particularly those who gave oral evidence. The Committee also wishes to express its high appreciation of the valuable assistance given by the Member-Secretary, Dr. A. Seetharamiah.

Sd/-(G. P. KANE)
Chairman

Sd/- (K. K. SAHNI)
Member

Sd/-(K. VYASULU)
Member

Sd/-(J. S. AHLUWALIA)
Member

Sd/-(A. SEETHARAMIAH)
Member-Secretary,
15-12-1961

APPENDIX I

NO. CH(I)-2/(81)/60

GOVERNMENT OF INDIA

MINISTRY OF COMMERCE AND INDUSTRY

New Delhi, the 10th October, 1960

OFFICE MEMORANDUM

Sub:—Setting up of a Committee for preparation of a plan for the Development of Petro-chemical industries during the Third and the Fourth Five-Year Plans.

During the last few years in many advanced countries of the world, products such as synthetic rubber, plastics, insecticides, detergents and organic solvents have been made increasingly as petro-chemicals. In view of the rapidly rising demands for such products in the country and the likely availability of suitable petroleum fractions for their production in the next few years, Government recognise the need to encourage the development of petro-chemical industries. It has, therefore, been decided to set up a Committee to study the subject in all its aspects so as to evolve a plan for organising such industries during the Third and the Fourth Five-Year Plans. The composition of the Committee will be as follows:

- (1) Dr. G. P. Kane, Senior Industrial Adviser (Chemicals), Development Wing, Ministry of Commerce & Industry New Delhi. Chairman
- (2) Mr. E. P. Moon, Adviser (Planning), Planning Commission, New Delhi. Member
- (3) Shri K.K. Sahni, Joint Secretary, Ministry of Steel, Mines and Fuel, New Delhi. Member
- (4) Dr. J. S. Ahluwalia, Chemical Engineer, Ministry of Steel, Mines and Fuel, New Delhi. Member
- (5) Shri K. Vyasulu, Chief (Industry), Planning Commission, New Delhi. Member
- (6) Dr. A. Seetharamiah, Development Officer (Leather and Rubber), Development Wing, Min. of Commerce & Industry, New Delhi. Member-Secretary

2. The terms of reference of the Committee will be:

- (a) An assessment of the types and quantities of materials whose production may have to be organised in petro-chemical Industries.
- (b) A study of the integrated pattern of production of petro-chemicals in advanced countries and to evolve a suitable pattern for development in India.
- (c) To assess the extent to which aromatic as well as aliphatic raw materials may have to be produced as petro-chemicals during the period 1961 to 1971.
- (d) To recommend the pattern of development of petro-chemical industries in the country.

3. The Committee would submit its report within four months from the date of this order.

Sd/- G. L. MEHTA

Deputy Secretary to the Govt. of India.

APPENDIX II

NO. CH(I)-2/(81)/60

GOVERNMENT OF INDIA

MINISTRY OF COMMERCE AND INDUSTRY

New Delhi, the 2nd November, 1960

OFFICE MEMORANDUM

Sub:—Setting up of a Committee for preparation of a plan for the development of Petro-chemical industries during the Third and the Fourth Five-Year Plans.

The undersigned is directed to refer to this Ministry's Office Memorandum of even number, dated the 10th October 1960 on the above subject and to say that the following may be substituted for para 2(b) of the said Office Memorandum.

"To evolve a suitable pattern for development in India in the context of the integrated pattern of production of petro-chemicals in advanced countries."

2. It has also been decided that since Shri E. P. Moon, Adviser (Industry), Planning Commission, New Delhi is busy with other work he may not be burdened with the membership of the Committee.

Sd/- G. L. MEHTA

Deputy Secretary to the Govt. of India

- (1) Dr. G. P. Kane, Senior Industrial Adviser (Chemicals) Development Wing, New Delhi.
- (2) Shri E. P. Moon, Adviser (Industry) Planning Commission, New Delhi.
- (3) Shri K. Vyasulu, Chief (Industry), Planning Commission, New Delhi.
- (4) Shri K. K. Sahni, Joint Secretary, Ministry of Steel, Mines and Fuel (Deptt. of Mines and Fuel) New Delhi.
- (5) Dr. J. S. Ahluwalia, Chemical Engineer,
Ministry of Steel, Mines and Fuel (Deptt. of Mines and Fuel) New Delhi.
- (6) Dr. A. Seetharamiah, Development Officer,
(Leather and Rubber), Development Wing, New Delhi.

APPENDIX III

INFORMATION REQUIRED REGARDING THE AVAILABILITY OF PETROLEUM RAW MATERIALS FOR CHEMICAL INDUSTRY IN INDIA

- (i) Production Pattern
- (ii) Present Crude throughput
 - (a) Tons per annum
 - (b) Type of Crude(s)
 - (c) Capacity
 - (d) Expansion programme
- (iii) Refinery Gas:
 - (a) Quantity
 - (b) Composition
 - (c) Present use
 - (d) Price
- (iv) Reforming:
 - (a) Type (Thermal, Catalytic Platforming or other)
 - (b) Capacity/present throughput
 - (c) Composition of the feed-stock (% Aromatics in particular)
 - (d) Octane of the reformat
 - (e) Quantity and composition of the reformat
 - (f) Quantity and composition of reformer gas
 - (g) Possibility of using the reformer, for the production of BTX and naphthalene
- (v) Cracking:
 - (a) Type (Thermal or Catalytic)
 - (b) Capacity/present throughput
 - (c) Quantity and composition of cracked gas
 - (d) Possibility of using cracked distillates and bottoms/slurry for the manufacture of aromatics, carbon black, etc.
- (vi) Coking:
 - (a) Type (Delayed or Fluid)
 - (b) Capacity/present throughput
 - (c) Quantity and composition of coker gas
 - (d) Quantity and analysis of coke possibility of using coker products as raw material for petro-chemicals.
- (vii) Naphtha:
 - (a) Availability of surplus Naphtha for (1) Cracking, (2) Fertiliser manufacture
 - (b) Price
- (viii) Slack Wax:
 - (a) Availability for cracking to produce higher olefins etc.
 - (b) Price
- (ix) Solvents:
 - (a) S.B.P. Spirits
 - (b) Aromex
 - (c) Other
- (x) Other materials that could be used as feed stocks for petro-chemicals

APPENDIX IV

LIST OF PERSONS WHO GAVE EVIDENCE BEFORE THE COMMITTEE

Shri T. P. Barat	}	M/s. Nowrosjee Wadia and Sons (Pvt.)
Dr. H. E. Eduljee		Ltd., Bombay.
Dr. C. J. Dadachanji	}	M/s. Union Carbide (India) Ltd.,
Dr. H. C. Rijawat		Calcutta.
Mr. J. Dick		M/s. Imperial Chemical Industries (India)
		Pvt. Ltd., Calcutta.
Dr. K. A. N. Rao	}	The Indian Chemical Manufacturers
Shri J. H. Doshi		Association, Bombay.
Shri Sardesai		
Shri Shah		
Mr. P. D. Tew	}	M/s. Burmah Shell Oil Storage and
Dr. R. Gonsalves		Distributing Co. Ltd., Bombay.
Shri R. S. Beardmore		
Mr. W. J. Spicer	}	M/s. Standard Vacuum Oil Co. Ltd.,
Mr. E. G. Earnst		Bombay.
Dr. A. M. Desai		
Shri Arvind N. Mafatlal	}	M/s. Standard Mills Co. Ltd., Bombay.
Dr. M. S. Patel		
Shri Narain Singh	}	M/s. Caltex (India) Ltd., Bombay.
Mr. Paul Thomson		
Shri M. G. Menon	-	The Indian Refineries Ltd., New Delhi.
Dr. C. J. Dadachanji	}	Organic Chemicals Panel of the Develop-
Dr. A. M. Desai		ment Council for Organic Chemicals
Mr. J. Dick		Industries.
Shri S. L. Venkiteswaran		
Dr. V. E. Henny	..	French Petroleum Institute, Paris.



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APPENDIX V (a)

ASSAM OIL COMPANY LIMITED, DIGBOI, ASSAM

(1) Production Pattern

The highlights of our Refinery Policy are as follows:—

- (a) Motor Spirit Minimum.
- (b) Kerosene and Wax Maximum.
- (c) Lubricating Oil SBP Spirits, and our special minor products e.g. Wash Oil 'C', Aromex, Solar Oil, Min. Colza, Min. Turps. Maximum to the extent markets can absorb or we are capable of producing. This is with a view to saving country's Foreign Exchange to the extent possible.
- (d) Assam's requirements Meet in full as far as practicable.
- (2) (a) Crude Throughput 440,000 tons per annum.
- (b) Characteristics of Crude Mixed base in nature consisting of 11-12% recoverable paraffin wax.
- (c) Capacity of the Refinery Depending on product pattern between 400,000 and 500,000 tons per annum.
- (d) Expansion programme None in hand.

(3) Refinery Gas

(a) The total gas available is made up as follows:—

- (i) During distillation of crude oil and production of SBP Spirits and Cracked Gasoline. 202,000 cu. ft./day (6" water pressure)
- (ii) High Pressure Gas ex Dubbs plant 70,000 cu. ft./day.
- (iii) Low pressure Gas:
Soda Washing of pressure 48,000 cu. ft./day (6 inch water pressure)
Distillate from the cracking process. 320,000 cu.ft/day.

(b) Composition Typical Composition of the various gases are shown below:

Composition	Gas ex Crude Distillation	Gas ex Dubbs Cracking		Gas ex re-running of pressure Distillate
		Low Pressure	High Pressure	
Methane	32.1	39.4	59.2	—
Ethylene	—	3.7	3.6	2.3
Ethane	6.2	14.2	13.4	7.3
Propylene	—	8.5	6.0	8.5
Propane	19.4	12.7	8.3	19.9
Butylenes	—	7.1	2.6	17.8
Butanes	27.0	5.6	1.7	17.8
Pentanes and Heavier	15.3	8.7	5.2	26.4

- (c) Present use All the available gas is used for internal requirements chiefly in the Refinery.
- (d) Price Since we have no surplus, the question does not arise.

- (4) *Reforming* There is no such unit here.
- (5) & (6) *Cracking/Coking*
- (a) Type Dubbs Thermal Cracking Unit producing gas, pressure distillate and Petroleum Coke. We have two units but one runs at a time.
- (b) Capacity —Unit I 1000 barrels/day.
Unit II 800 barrels/day.
- (c) Quantity and consumption of cracked gas. See III(b) above.
- (d) Possibility of using cracked distillate and bottom slurry as raw materials for petro-chemicals. The present output of cracked distillates and bottoms are utilised for the production of M.S., Inf. Kero., Malariol, T.D.O., Wood Oil, Sleeper Oil. It is possible to produce 200,000 g.p.m. of cracked gasoline and 150,000 g.p.m. of P.D. Bottom at the expense of M.S. and T.D.O. respectively but this would involve capital expenditure.
- (e) *Coke*
- (i) Make Average 11,000 tons/month.
- (ii) Quality Typical analysis is given below
- | | |
|-------------------------|----------------------|
| Moisture | 5 to 12% by wt. |
| Volatile matter | 10 to 12% by wt. |
| Fixed carbon | 90% by wt. |
| Ash | 0.2 to 0.45% by wt. |
| Total sulphur | 0.4% by wt. maximum. |
| Calorific value | 15,590 BTU/lb. |
- (7) *Naphtha*
- (i) Light Naphtha. (Gasoline or Motor Spirit including Cracked Gasoline) Make about 200 lacs gallons p.m. used as Motor Spirit.
- (ii) Heavy Naphtha (Light Kerosene/Min. Turps)—No Surplus is available since the entire production is used for the manufacture of Kerosenes/Vap. Oil/Min. Turps.
- (8) *Slack Wax*
(Heavy Wax distillate).
All waxy products including slack wax from which no commercial wax can be recovered are included in the cracking stock for Dubbs Plant.
- (9) *Solvents (SBP Spirit)*
We are capable of producing 55°/115°, 60°/120°, 80°/110° and 100°/130° —only one grade a time. This production is possible at the expense of Motor Spirit gallon for gallon.
- Aromex*
A small amount of Aromex is supplied for chemical formulations either to the D.G.S. & D. or to Burmah-Shell. The remainder is utilised for the production of Powerine, Tractor Fuel, Furnace Oil etc.
- (10) Other surplus to be used for petro-chemical manufacture: None available.

APPENDIX V (b)

STANDARD VACUUM REFINING COMPANY OF INDIA LIMITED, BOMBAY

Information required regarding the availability of Petrochemical raw materials from Refineries.

Production :

Production pattern is primarily governed by the market demand for individual products and crude running capacity. Other factors such as crude characteristics also play an important role in controlling the product distribution. Products to be manufactured in 1961, as envisaged today, are as follows:—

	<i>Metric Tons/year</i>
Motor gasoline	337,000
Kerosenes	204,000
Diesels	535,000
Furnace Oil (Including Hot Heavy Stock)	546,000
Asphalts	145,000
Liquified Petroleum Gas ..	3,000
Jute Batching Oil	66,000

(ii) Crude

Present throughput Capacity:

38,876 B/CD in 1960.

39,000 B/CD projected for 1961.

Current capacity of the refinery based on last year's performance is anticipated to be 39,000 B/CD for 1961. With constant inspection, maintenance and relatively minor modifications of the plant facilities, resulting from accumulating experience, it would be possible to increase the refinery capacity to 40—42,000 B/CD. However, it is difficult to predict at this time how much of this increment would be realised during the next 12—18 months.

Expansion programme:

Apart from the normal practice of improving refinery operations to increase the capacity as noted above, there is no new definite approved expansion programme in hand at present.

(iii) Refinery Gas

(a) Quantity:

Approximately 1500—1600 FOE Bbls/CD

(b) Composition:

<i>Component</i>	<i>Mol %</i>
Inerts*	7.1
Methane	27.9
Ethylene	5.4
Ethane	15.4
Propylene	13.9
Propane	13.3
Butenes	4.8
Butanes	12.3

100.0

Sulfur 3000—5000 grains/100 SCF

*Inerts would contain carbon monoxide/ dioxide, Oxygen, hydrogen and nitrogen.

- (c) **Present Use:** During 1961, we project use of approximately 1300—1400 FOE/B/CD of gas as fuel for the refinery furnaces and the boilers. Balance of the gas (200—300 FOE B/CD) that may be available could be sold to the Tata Thermal Station.
- (d) **Price:** As yet Standard-Vacuum Refinery Company has not supplied any gas outside the refinery. If and when gas is sold, the gas price will undoubtedly be related to fuel oil C. & F., or possibly to the inland price of fuel oil, as gas normally represents a source of commercial energy competitive with fuel oil.
- (iv) **Reforming**
- (a) **Type:** Thermal Reforming.
- (b) **Capacity/Present Thruput:** 4000 B/CD
- (c) **Composition of feed-stock:** Boiling Range: 78 to 140° C. (approx.)
*API: 60 (approx.)
Aromatics: 8-9%
- (d) **Octane of Reformate:** About 65—70 Research Octane (Projected 1961 Operations)
- (e) **Quality of Reformate:** About 75—80%.
- (f) **Composition of Reformate:** The Combination Unit, available with the Stanvac Refinery, does not permit obtaining plant data on the reformate composition, etc. since normally it is obtained as a mixed stock with catalytically cracked naphtha. Thermally reformed naphtha does not normally provide a source material for BTX and naphthalene. Reforming operation and severity are controlled to a great degree by the octane requirements and size of the export gasoline markets available to Stanvac. In future years these markets are expected to shrink considerably, although it is not known to what extent. Consequently, products available from the Thermal Reformer will probably play only a minor role so far as overall refinery operations are concerned.
- (g) **Quantity of net gas:** Approximately 200—300 FOE B/CD
- (h) **Composition of reformed gas:** Same remarks apply as under (f) above.
- (v) **Cracking**
- (a) **Type:** Catalytic Cracking.
- (b) **Capacity/Present Thruput:** 9500 B/CD
- (c) **Quantity of net gas:** Approximately 750—850 FOE B/CD
- (d) **Composition of gas:** As noted above, separate composition of the gas from plant data is not available.
- (e) **Cracked Distillation:** Cracked distillate (gas oil range) as obtained from the combination Tower contains some aromatic hydrocarbons of relatively high molecular weight. However, laboratory data indicates that the 60 (approx.) BMCI (Bureau of Mines Correlation Index) obtained for the aromatic extract is much lower than 120—130 BMCI normally desired by Carbon

(f) Bottoms/Slurry:

Black manufacturers. Data available at present do not indicate suitability of any of the distillate stocks to economically manufacture low molecular weight aromatics.

Pure cracked bottoms/slurry is not obtainable in the combination tower. It forms a small percentage of the residual stock obtained from the tower and is utilised for asphalt, hot heavy stock and furnace oil manufacture.

(vi) Coking

(vii) Naphtha

(a) Availability:

Refinery does not anticipate any naphtha surplus until 1963-64. After this date, curtailment of export gasoline market is anticipated. The resulting naphtha would be absorbed by:—

- (a) new products to be manufactured by the Refinery;
- (b) sale of about 46,000 tons/year of naphtha to the Trombay Fertilizer Plant; and
- (c) utilisation of about 100,000—150,000 tons/year of naphthas by the Stanvac petro-chemical project.

With these provisions for utilizing naphtha in forms other than motor gasoline it is believed SVRC will be roughly in naphtha balance.

(b) Price:

Standard-Vacuum Oil Company has never sold naphtha; our opinion regarding its price must therefore be hypothetical to the extent that we assume conditions at the time of any future sale. If raw naphtha is in serious over-supply and represents a possible limiting factor on refinery thruputs, naphtha would probably be priced so as to be competitive with whichever petroleum product is available to a consumer as an alternate. For most end-uses naphtha will have to compete with fuel oil, and naphtha price might therefore be expected to be based on, say, the inland fuel oil selling price with appropriate adjustments for excises. However, if naphtha is not in over-supply, it could be made available by the refineries, but at the expense of some other fuel product. The naphtha price would in that case probably be based on, say, the inland selling price of gasoline with appropriate adjustments for excises. The availability of naphtha in the future will be heavily influenced by the installation of petro-chemical plants, fertilizer plants and consumption of gasoline. We, therefore, believe that a fixed pricing basis for naphtha at this stage is impossible, and that future naphtha contracts may very well vary widely in price

depending on the supply position existing at that time. Any naphtha contract price would also be influenced by quality requirements of the consumer as high purity, narrow boiling range cuts or other special features would have to reflect the more stringent manufacturing practices required.

(viii) *Slack Wax:*

Nil.

(ix) *Solvents:*

Refinery will initiate manufacture of the following solvents beginning 3rd quarter of 1962:

- (a) Hexane: 150/158° F. Cut range.
- (b) Pegasol 1425: 131/239° F. Cut range.

(x) *Other Materials:*

Nil



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APPENDIX V (c)

BURMAH-SHELL REFINERIES LIMITED, BOMBAY

(i) *Production Pattern* This is already forwarded to Ministry of Steel, Mines & Fuel on a regular basis.

(ii) *Crude Throughput*

Present	approx : 3 million tons/annum.
Proposed expansion	approx : 4 million tons/annum including manufacture of lubricating oil basics.
Type of crude	currently light Iranian export (mixed-base type).

(iii) *Refinery Gas*

(a) Quantity 200—250 tons/day based on present forecast of operations

(b) Typical composition :

	wt.
hydrogen sulphide	4.2
carbon dioxide	1.7
hydrogen	3.4
nitrogen	5.0
oxygen	0.2
carbon monoxide	0.4
methane	4.3
ethylene	1.5
ethane	8.2
propylene	9.9
propane	19.9
butylene	9.4
butane	30.9
other	1.0
	100.0

The quantity and composition of the gas vary depending on the overall refinery programme, being influenced by individual plant throughputs, shutdowns, processing severity etc. The above gas is obtainable after estimated Burmah requirements have been met.

(c) Present uses are :

- (1) fuel for refinery processes.
- (2) for blanketing storage vessels containing chemicals which react with air.
- (3) as bleeds for instrument tappings.
- (4) as fuel for gas-driven engines.

As regards price you will appreciate that as we own neither the crude oil nor the products but only process, this is the concern of Burmah-Shell Oil Storage and Distributing Co. of India Ltd. However, we would point out that price depends on the quantity and quality of the material required, the pressure at which it would be supplied, the steadiness of off-take of the material, capital expenditure involved within B.S.R., existing commitments for other products etc. and the price, therefore, would have to be considered in the light of the circumstances existing at the time that individual contracts are negotiated.

(iv) *Reforming*

Type	Catalytic (Platforming)
Capacity	800 tons/day (max.)
Typical composition of feed	paraffins 60% wt. naphthenes 28% wt. aromatics 12% wt.

Octane of reformat	.. .. .	70—95 (Research, unleaded).
Quantity of reformat	.. .. .	375—700 tons/day.
Typical composition of reformat	..	paraffins 40—65% wt. aromatics 35—60% wt.
Quantity of gas	.. .. .	40—1100 tons/day.
Typical composition of gas	.. .. .	hydrogen 13.5% wt. methane 9.0 ethane 21.0 propane 33.0 butane 23.5

The reformat contains, amongst other things, toluene and xylene and small amounts of benzene. The naphthalene content of the reformat is not known but is certainly very small. The gas and reformat compositions vary according to the operation of the platformer which is adjusted to meet the overall refinery programme.

(v) *Cracking*

Type	.. .. .	Catalytic.
Capacity	.. .. .	2100 mt/day (max.)
Present throughput	.. .. .	1450 mt/day
Quantity of gas	.. .. .	140—160 tons/day.
Typical composition of gas	..	hydrogen sulphide 8.3% wt. hydrogen 2.5 nitrogen 7.4 methane 5.2 ethylene 2.7 ethane 6.8 propylene 17.6 propane 7.3 butylene 15.8 butane 22.0 other 4.4

The cracked distillates would not be good feedstocks for manufacture of benzene, toluene or xylene, but certain fractions might be suitable for naphthalene production, though the present refinery equipment cannot produce such a fraction. The heavy cracked distillates would be used for production of carbon black, but it is believed that the yield and quality of the carbon black would not be good.

The gas composition and quantity can vary over a wide range with changes in throughput, conversion, cracking temperature, recycle ratio, gasoline quality etc. depending on the overall refinery programme.

(vi) *Coking*

Process not installed.

(vii) *Naphtha.*

(a) None available at the moment, as this is a component of our Motor Spirit. We have contractual commitments for a considerable tonnage of Naphtha for fertilizer manufacture from end 1961 and further quantities are being held as option for other possible purchasers. As any sales of Naphtha as such disturb the existing product pattern of the refinery, we have to consider with our marketing associates the replacement of and the effect on the quality of existing saleable products. The above is on the basis of our existing throughput. In the event that expansion at B.S.R. is sanctioned, we can confirm that additional Naphtha will be available. We wish to point out at this stage that Fertilizer manufacture based on a gasification process can use, as a feed to this process, any liquid fuel, e.g. crude oil or furnace oil, and that this need not be confined to Naphtha. The merits of any particular case must obviously be examined at the appropriate time.

(b) As regards price, our comments shown in Refinery Gas (iii) (d) will apply generally.

(viii) *Slack Wax*

Not available at the present time. In the event that B.S.R. expansion including a Lub-oil plant is sanctioned, then certain quantity could be made available.

(ix) Solvents

S.B.P. Spirits Proposal for the manufacture of some 20,000 to 24,000 tons/annum, awaiting Government's approval.

Aromex

We presume this would mean some form of aromatic extract. We have none available at the present time. Should the proposed Lubricating Oil plant be installed, there would be available a furfural extract from the lubricating oil treatment which would make a suitable feed-stock for Carbon Black manufacture.

(x) Other materials.

Acid Sludge—Presently 3,500 tons per year. In the event that expansion of the refinery capacity is sanctioned, additional acid sludge would be obtained. When special Boiling Point Spirits manufacture at B.S.R. has been approved, some additional acid sludge from the treatment of the S.B.P. spirits will also be available but the quantity will be small.



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APPENDIX



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APPENDIX V (d)

CALTEX OIL REFINING (INDIA) LIMITED, VISAKHAPATNAM INFORMATION REGARDING THE AVAILABILITY OF PETRO-CHEMICAL RAW MATERIALS

(i) *Approximate Production Plan*

									BPCD
Mogas	..	..	..	..	..	..	..	..	4,200
Superior Kerosene	..	..	..	..	..	..	..	..	2,346
Inferior Kerosene	..	..	..	..	..	..	..	..	132
HSD	..	..	..	..	..	..	..	..	4,179
Light Diesel Oil	..	..	..	..	..	..	..	..	1,800
Fuel Oil	..	..	..	..	..	..	..	..	4,350
Low Sulphur Fuel Oil	..	..	..	..	..	..	..	..	920
(ii) (a) <i>Present crude Throughput</i>	..	..	..	..	..	..	..	..	19,000 BPCD
(b) <i>Capacity of Refinery</i>	..	..	..	..	..	..	..	..	20,000 BPCD may be possible at a later date.

(c) *Type and Characteristics of Crudes:* Two types of crudes are being processed in our Refinery the characteristics of which are given below:—

	Crude	Minas	Iranian
Gravity, ° API		35.8	34.1
Sulphur, wt. %		0.06	1.34
Carbon Residue, Ramsbottom, wt. %		3.3	2.9
Pour point, OF		+95	—5
Calorific Value (Gross, Calculated)		19,60	19,360
U.O.P. Characterisation Factor		12.2	11.5
Bureau of Mines Correlation Index		21.7	37.3

Although we have no objection to the expanding the Refinery in the future, it would depend on the demand for products and the policy of the Government.

(iii) *Refinery Gas:*

- (a) *Quantity:* The average quantity of gas available per day would probably be about 8700 pounds; however, the quantity will vary considerably from day to day and during a two-week period each year will be nil. There are no storage facilities for this gas, therefore, no guarantee could be made as to the quantity that could be supplied.
- (b) *Composition:* The C1, C2, C3, C4 fractions cannot be detailed. In addition to the hydro-carbons present there are also quantities of Nitrogen, Oxygen, Carbonyl Sulphide, Hydrogen Sulphide, Carbon Dioxide and Carbon Monoxide present. The BTU of the gases will vary from 16,000 to 21,000 BTU/lb. The Carbon/Hydrogen ratio will vary between 300 to 4.7.
- (c) *Present Use:* The gas produce in the Refinery is mostly used as fuel gas in the process furnaces. A portion of it in liquid form is required for use as solvent for the propane deasphalting Unit.
- (d) *Price:* No price has been set for this gas as it is doubtful that it can be used for anything but Refinery fuel.

(iv) *Reforming:* We do not have any reforming facilities.

(v) *Cracking:*

- (a) *Type:* We have a Model IV Catalytic Cracking Unit.
- (b) *Capacity and Present Throughput:* The design capacity of our unit is 8400 BPSD of fresh feed when using new catalyst. Our present operating plants are based on a fresh feed rate of approximately 5,000—5,500 BPSD which is close to the capacity of the unit when operated with previously used catalyst to maximise middle

distillate production and minimise gasoline production and also to minimise Catalyst costs. Due to our continuing efforts to maximise middle distillate and minimise gasoline production, the operating factor for this unit is at present in the region of 62%.

- (c) *The quantity and composition of cracked gas*: The quantity of gas produced varies between 3500--5000 pounds per hour. A representative composition of the gas produced is given below. Both the quantity and quality of the gas are variable depending upon the particular operation of the cracking unit.

Typical Analysis of Fluid Catalytic Cracking Unit Gas

	Gas Volume%
Hydrogen Sulfide	0.1
Carbon Di-oxide	2.4
Oxygen	0.2
Carbon Monoxide	4.0
Hydrogen	55.3
Nitrogen	14.2
Methane	1.5
Ethane	5.6
Ethylene	3.1
Propane	2.1
Propylene	7.1
Iso Butane	0.7
Normal Butane	0.3
Butylene	1.4
Iso Pentane	0.4
Normal Pentane	0.4
Pentylene	1.2

- (d) *Utilisation of cracked Distillates and Slurry*: The light cycle gas oil from the cracking unit which contains about 35 percent aromatics is the most suitable stock for the production of these compounds. However, this stock is used as cutter stock in our fuel oils and hence is not available normally for the production of aromatics. Also a major investment would be required for suitable process facilities to separate out and purify the aromatic compounds in this process stream.

The typical inspections on the cracking Unit slurries that could be made available for carbon black manufacture are given below:—

Slurry Type	Minas	Iranian
<i>Inspections</i>		
Gravity °API	31	10.22
Carbon Residue, Ramsbottom, wt. %	0.40	4.7—0.3
Pour Point, °F	+110	+95—100
Sulphur, wt. %	0.15	2.8—1.30
Viscosity, Kinematic centistokes @ 210°F	4.0	8.2—5.3
Bureau of Mines Correlation Index	28.8	87.4—54.0

However, normally no slurry is produced as a unit product when cracking Minas feed stocks but rather this stock is cracked to extinction. Similarly, although long term operations with Iranian feeds have not been firmed up, we would expect that little or no Iranian FCC slurry would be available from these operations.

(vi) *Coking*: We do not have any coking facilities.

(vii) *Naphtha*:

(a) *Availability of Surplus Naphtha for Cracking, Fertiliser.*

Manufacture: On the basis of our present operating plans we could produce about 150 to 200 tons per day of Naphtha. However, the actual availability of Naphtha will depend on the quantities of surplus gasoline we will have and the export market

for Gasoline. This in turn is dependent on the crude run that will be permitted. In other words the maximum amount of Naphtha will be sold as Gasoline and any surplus will be sold as Naphtha. If additional Naphtha is required by the Government, it would be possible to produce even more than indicated above by increasing the capacity of the Refinery.

- (b) *Price*: No price has been established to-date for Naphtha as this will depend to a large degree on whether it is a surplus product or produced at the expense of marketable Gasoline. Surplus Naphtha will probably have its price tied to Fuel Oil prices but it will carry a premium for BTU content, low Sulphur content higher handling costs, etc.

(viii) *Slack Wax*: We do not produce any Slack Wax.

(ix) *Solvent*: We do not produce any solvents

(x) *Other Materials*: None.



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APPENDIX V (e)

INDIAN REFINERIES LIMITED, NEW DELHI

	Gauhati Refinery Tons/yr.	Barauni Refinery Tons/yr.
Design crude thruput	750,000	2,000,000
(1) Aviation gasoline (73 ON. clear)	—	10,000
(2) Motor gasoline	160,200	375,000
(3) J.P.4	—	120,000
(4) ATF (—46°C) freezing pt.)	—	68,000
(5) Superior Kerosene	104,000	154,000
(6) Inferior Kerosene	59,700	47,000
(7) High speed diesel oil	119,000	376,000
(8) Light Diesel Oil	64,500	168,000
(9) JBO	—	90,000
(10) Furnace Oil (Regular)	—	118,000
(11) Furnace Oil (Residual)	113,200	102,000
(12) LPG	—	20,000
(13) Coke	39,000	67,000
(14) Bitumen	—	120,000
(15) Aromex	36,000*	—
(16) Gases	34,000	118,000
(17) Losses	20,400	47,000
Gas for Refinery & Power Plant-fuel	All gases under item 16	All gases under item 16
Fuel oil (res.) for Refinery & power plant fuel	To be taken from item 11.	To be taken from item 16.
TOTAL	750,000	2,000,000

NOTE: (1) The product pattern figures given above will be realised when the Refineries are operating at their full capacity.

(2) The pattern for the Barauni Refinery is tentative.

(ii) Type and characteristics of crude: Both the refineries have been designed to process Nahorkatiya crude.

The properties of the crude oil as reported by the Russians are as follows:—

Specific gravity P420	0.3504
Molecular Wt.	195
Kinematic Viscosity at 50°C (Csk)	2.71
Pour Point °C	30
Wax content %	13.7
Sulfur %	0.27
Nitrogen %	0.26
Sulfuric acid resins %	17
Silica gel resins %	6.57
Asphaltenes %	0.25
Carbon Residue % (Conradson)	1.49
Ash %	0.01
Water %	0.21

*Shows the quantity available as such for sale.

Distillation: % vol. distilled:

—IBP	50°C
— 5	87
—10	113
—20	150
—30	197
—40	250
—50	295

The crude is of relatively low density ($P^{20}_4=0.851$), low sulfur content (0.22%), average percentage of resinous matter and a very high percent of paraffins (15.6% of paraffins with fusion point of 55°C). The crude is of unusual nature because it has, besides a high percentage of paraffins, a high content of aromatics and naphthenes. The straight run gasoline, (60°—145°C) contains nearly 22% by weight of aromatics.

Of particular interest is the fact that the fraction boiling between 122 and 145°C contains 37% of Aromatics (paraxylene—5.4%, metaxylene—17.1%, Orthoxylene—6.2, ethyl benzene—83%).

The design capacities of the Gauhati and Barauni Refineries are 0.75 and 2 million tons per year respectively. Normally, they can be expected to run about 10% more over the design thruput. Expansion programme for either of the refineries have not been envisaged at present.

(iii) Refinery gases:

Refinery	Unit	C1/Cs	C3's	i-C4	n-C4 = C4	C5+	total t/yr.
Gauhati	Crude	Dist—	1,800	3,600	4,600	—	10,000
	Coking	12,000	6,700	400	1,400	2,000	24,000
	Total						34,000
Barauni	Complete details not available; see (vi) below 118000						

The gases produced at the two refineries are 34,000 t/yr at Gauhati and 118,000 t/yr at Barauni. As planned, the entire production of gases will be used as refinery fuel, the excess requirement of fuel being made up by fuel oil. Since it has been planned to use the gases for internal consumption no price for these has been fixed.

(iv) & (v) Neither of these refineries will be having a Reforming or a Cracking unit.

(vi) The coking units at Gauhati and Barauni will be of Delayed Coking type.

Refinery	Coking Unit Capacity t/yr.	Coking Unit Gas analysis (wt.% of total yield)									
		H ₂	CH ₄	C ₂ H ₆	C ₂ H ₄	C ₃ H ₆	C ₃ H ₈	C ₄ H ₈	i-C ₄	n-C ₄	C ₅ total t/yr.
Gauhati	3,00,000	—	50	—	28	8.33	1.67	5.8	6.2	—	24,000
Barauni	5,60,000	0.6	21.8	18.5	6.7	17.5	14.4	11.5	9.0	—	84,000

Petroleum Coke:

The quantity and composition of coke produced at Gauhati Refinery are as follows:—

Quantity t/yr	..	..	..	..	39,000
Apparent Density	..	..	..	..	about 1.
Moisture % by wt.	..	..	..	..	5—12 (depending upon weather conditions)
Volatiler matter % wt.	..	..	..	..	10—15 (dry basis)
Fixed carbon % wt.	..	..	..	..	90—95
Ash % wt	..	..	..	..	0.2—0.4
Sulfur % wt	..	..	..	..	0.5 (Max)
Calorific value kcal/kgm	..	..	..	..	8,800

The Barauni Refinery will be producing 67,000 tons of coke. The quality of the coke to be produced is not known definitely but is expected to be the same as that produced at the Gauhati Refinery.

As noted above, coking yields considerable quantities of gases. These gases form an excellent source of raw material for the manufacture of petrochemicals.

Some of the chemicals that could possibly be manufactured from each of these gases are given in the attached appendix. It is to be noted however that the economics of manufacturing any particular chemical is to be investigated first.

(vii) The total amount of gasoline produced at both the Refineries is about 535,000 tons/year. Since gasoline produced in the country is in excess over the demand, a certain quantity of it can be made available for manufacture of fertilisers etc. This point has to be decided by the Indian Oil Co., who will be handling the sale of products from the public sector refineries. The price basis for naphtha is yet to be decided. From available information, the Trombay Refineries (Private Sector) will be charging Hindustan Fertilisers for the supply of naphtha a price equivalent to the C.I.F. value of furnace oil which is about Rs. 78/- per ton. These refineries are able to accept this price presumably because part of the naphtha requirement could be replaced by the refinery waste gases. For a fertiliser plant situated at a distance from Gauhati and Barauni, the supply can only be liquid naphtha. This may not be profitable for us since the cost of the raw material may be of the order of Rs. 90/- per ton. It may be argued that since the gasoline produced is in excess over demand, some outlet has to be found even if the sale price is lower than the production cost. But it is possible to expand our inland market there by forcing of gasoline. These problems still remain to be tackled and as such it is difficult to give a definite price basis for the naphtha. (vide S-C/88 of 28th June 1960 from G.R. Kamat OSD IRL to S.K. Mukherjee Dy. Secy. Ministry of Mines & Fuel.)

(viii) Slack wax is a by-product from the jute batching oil unit at Barauni Refinery. The Gauhati Refinery does not produce any slack wax. According to the plan for the Barauni Refinery the entire quantity of slack wax (about 70000 t/yr) will be used as feed for the coking unit along with certain other streams. Slack wax constitutes about 12.5% of the total feed to the coking unit and the quantity and composition of gases from the coker unit as shown above (under item vi) are based on such a feed stock. No data on the yield and composition of gases resulting from coking the slack wax alone is available.

As a matter of interest, the results of thermal cracking of a composite mixture of slack wax and straight run short residuum is given below. These data are taken from the report on the laboratory studies conducted by the Russians. Here again, the results of cracking the wax alone have not been reported. The cracking was effected on a mixture of 80% straight run fraction (420°—490°C) and 20% of slack wax obtained from the JBO plant, in a two stage cracking process as follows.

(a) The first stage cracking of straight run fraction 420—495°C in a once-through operation (b) Second stage cracking of a blend of slack wax with the fraction (350—420°C) obtained by the first stage cracking. The yield of gases and the composition is as shown below:—

Charge stock	Total gases based on original feed stock wt %	Composition (wt. % of total gases)									
		H ₂	CH ₄	C ₂ H ₄	C ₂ H ₆	C ₃ H ₆	C ₃ H ₈	C ₄ H ₈	i-C ₄	n-C ₄	
Straight run short residuum (420—495°C) 80% and slack wax 20%	11	0.3	18.4	5.4	24.3	13.2	23.5	7.4	2.4	5.1	

The price basis for the product has not been decided yet.

(ix) *Solvents*: It has not been proposed to manufacture any grade of S.B.P. spirit in either of the two refineries. Part of the Aromex produced at the two refineries in the process of refining kerosene conforms to the ISI specifications for S.B.P. solvent, Highly Aromatic." The demand for this grade in the country is almost negligible.

(a) *Aromex produced at the Gauhati Refinery:* Two grades of Aromex will be produced at the Gauhati Refinery. The quantities and properties are shown below:

	Aromex I	Aromex II
Quantity tons/year	36,000	28,200
Sp. gr. at 15°C	about 0.9	about 0.9
Flash Point°C	37.8 (Min)	37.8 (Min)
Aromatic hydrocarbons % wt.	80	90
Distillation range °C	152—232	230—270

According to the information available the entire quantity of Aromex I and 15,100 tons of Aromex II can be utilised for conversion to more profitable products. Except for a very small quantity of Aromex I which will be blended with gasoline to improve its Octane Number no other use has been envisaged at present. It may be indicated here that the Aromex I and the available quantity of Aromex II (15,100 tons) from an excellent raw material for the manufacture of high grade carbon black. Other uses of Aromex are a solvent for insecticides and for the manufacture of high boiling aromatics.

(b) *Aromex from the Barauni Refinery:* A total quantity of 223,000 tons of Aromatic extract will be produced at the Barauni Refinery. Out of this 87000 tons will be blended with gasoline and 136,000 tons will be blended with fuel oil. The grades and the available quantities for conversion will be known only when the final project report on the refinery is received here.

Summary: Three products from the Gauhati and Barauni Refineries can be utilised as raw material for the manufacture of petro-chemicals and fertilisers.

They are (a) Refinery gases (b) gasoline and (c) Aromex.

(a) The combined output of gases from the two refineries is about 152,000 tons per year. Ordinarily these gases are to be used as refinery fuel. However, these gases can be converted to more useful and profitable products by judicious choice of processes. Some of the petrochemicals which could be manufactured from the gases are given in the attached Appendix. It may be suggested that the gases be used for the synthesis of methyl and ethyl alcohols which, besides being useful as such are versatile intermediates for the manufacture of a number of chemicals and for which there is a dearth in the country.

(b) A total of 535,000 tons of gasoline will be produced at the two refineries. Since the total production of gasoline in the country is over the demand, large quantities of naphtha can be made available for the manufacture of other chemicals. Since the gasoline from Nahorkatiya crude is rich in aromatics, the aromatics can be separated by extraction processes and later separated again into xylenes and lighter aromatics. The paraffinic portion can then be used as a raw material for fertilisers.

(c) The production of Aromex at the two refineries total up to 287000 t/yr. A part of Aromex could be blended with gasoline and a major part with fuel oil. By virtue of its high aromatic content, it forms a very good raw material for the manufacture of carbon black. It is understood that the entire quantity of carbon black (about 12,000 tons) is being imported at present, and as such manufacture of carbon black from Aromex should result in considerable saving in foreign exchange. Other suggested use of Aromex is the manufacture of synthetic detergents by sulfonation. The quality of the detergent that can be produced using Aromex as raw material can only be determined after a complete analysis of Aromex is obtained. The possibility of making high boiling aromatics from Aromex can also be investigated after the above data is available.

APPENDIX V (f)

PRODUCTION FROM BARAUNI REFINERY

(In metric/tons/year)

	1963	1964	1965
1. Aviation Gasoline	10,000	10,000	10,000
2. A.T.F. (—60°C)	—	120,000	120,000
3. Jet Fuel (—50°C)	—	68,500	68,500
4. Motor Gasoline	291,000	354,500	354,500
5. Superior kerosene	—	155,000	155,000
6. Inferior kerosene	373,500	47,100	47,100
7. H.S.D.	237,000	376,000	376,000
8. L.D.O.	136,000	159,700	164,600
9. Fuel Oil (Furnace Oil)	225,600	258,000	220,000
10. Aromex	—	—	—
11. Bitumen	—	79,000	105,000
12. L.P. Gas	20,000	20,000	20,000
13. Petroleum Coke	69,900	72,500	72,500
14. Motor Oil	—	9,100	12,000
15. Industrial Oil	—	25,200	34,000
16. Refinery Gas	—	—	—
TOTAL	1,363,000	1,754,600	1,759,200

1. The total production for 1963 has been estimated assuming that the first stage is in full production in January 1963, and the second stage in July 1963.

2. The total production for 1964 has been estimated assuming that the kerosene Refining Unit goes into operation in January 1964 but the Lubricating and Bitumen units come only in April 1964, when the third stage production pattern will be attained. The modified third stage production pattern of the Barauni Refinery after inclusion of Lub-Project and deletion of the JBO plant is yet to be received from the Russian consultants. The figures given here for 1964—66 are therefore provisional and some changes may occur.

APPENDIX VI
ORGANIC CHEMICAL INDUSTRIES

NOTE: (1) all figures in tons
(2) n.e shows not estimated.
(3) *shows items in current production

Material	Estimate of require- ment in		Approximate capacity in operation & licensed or approved currently	Gap to be covered by 1965-66	Remarks
	1965-66	1970-71			
(1)	(2)	(3)	(4)	(5)	(6)
I. Feed Stocks:					
1. Ethyl alcohol* ..	200,000	290,000	—	—	Expected to be fully available from molasses by fermentation.
2. Ethylene	50,000	165,000	—	—	To be developed from petroleum.
3. Propylene	20,000	70,000	—	—	Do.
4. Butylenes (Butane Isobutane) ..	58,000	185,000	—	—	Do.
5. Acetylene* ..	29,000	60,000	—	—	4th plan demands to be met from petroleum sources to the extent of 40% or so.
6. Benzene	80,000	170,000	—	—	About 20/30000 tons to be derived from petroleum as supplement to coke oven based production.
7. Naphthalene ..	20,000	40,000	—	—	About 6/7000 tons production as O-xylene as supplement to production from coal tar based Naphthalene.
8. Toluene and Xylenes.	n.e	n.e			
II. Major Organic Chemicals:					
1. Methanol ..	25,000	70,000	Nil	25,000	
2. Formaldehyde 37%	30,000	76,000	13,000	17,000	Further capacity to be linked to methanol.
3. Acetic Acid* ..	29,000	57,000	20,000	9,000	Further capacity to be linked to Cellulose Acetate.
4. Acetone*	9,500	18,000	8,000	1,500	
5. Dodecyl Benzene ..	8,000	24,000	Nil	8,000	Linked to tetramer production.
6. Ethylene Dichloride ..	9,000	n.e.	4,000	5,000	Excludes captive use for PVC.

(1)	(2)	(3)	(4)	(5)	(6)
<i>II. Major Organic Chemicals (contd.)</i>					
7. Styrene Monomer	33,000	71,000	25,000	8,000	
8. Phenol	18,000	43,000	16,000	2,000	
9. Aniline	4,000	10,000	1,750	2,000/2500	
10. Phthalic anhydride	13,000	28,500	9,000	4,000	
11. Caprolactum ..	12,000	28,000	10,000(?)	2,000	linked to Nylon production.
12. Phthalates ..	8,000	20,000	9,000	—	
13. Other Plasticizers	2,000	6,000	1,000		
14. Ethylene Oxide	5,000	10,000	1,500	3,500	
15. Carbon Tetrachloride and chloromethanes.	8,000	10,000	3,500	4,500	
16. Trichlor ethylene and related solvents.	6,000	15,000	7,000		
17. Carbon black* ..	35,000	70,000	25,000(?)	10,000	
18. Carbon disulphide*					
<i>III. Other Organic Chemicals</i>					
1. N. Butanol ..	6,000	12,000	5,500	—	
2. Ethyl Hexanol ..	5,000	15,000	1,700*	1,500*	Extension to 3500 tons is under consideration.
3. Butyl and other acetates.	6,000	12,000	4,000	—	
4. Monochloro-acetic acid.	2,000	4,000	2,500	—	
5. Ethyl chloride ..	1,500	3,000	—	1,500	
6. Diacetone alcohol	3,000	6,000	2,500	1,500	
7. Acrylonitrile ..	2,000	6,000	—	2,000	
8. Maleic anhydride ..	2,000	5,000	300	2,000	
9. Pentaerythritol ..	1,500	4,000	2,100	—	
10. Hexamine	1,000	3,000	600	400	
11. Melamine	1,800	5,400	—	1,800	
12. Dicyandiamide ..	1,500	—	—	1,500	
13. M. Cresol	1,000	3,000	—	—	may be derived from coal tar.
14. Rubber accelerators and antioxidants.	4,000	8,000	2,500	1,500	
15. Acetanilide ..	2,000	—	1,000	1,000	
16. Dimethyl Tenephthalate.	3,000	—		3,000	linked to Terylene
17. Citric acid ..	3,000	—	3,000	—	
18. Other Organic acids such as oxalic formic, tartaric etc.	2,000	—	1,500	n.e.	
19. Salicylic acid* ..	1,500	—	1,500		
20. Camphor	1,000/1,500	—	2,000	—	
21. Toluene diisocyanate	1,000	4,000	nil	1,000	
22. Propylene glycol	2,000	6,000	nil	2,000	
23. Glycerine*					
24. Fatty acids*					

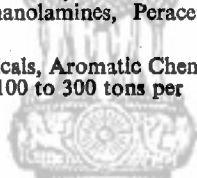
	(1)	(2)	(3)	(4)	(5)	(6)
IV. Dyestuff Intermediates						
1. Anthraquinone ..	2,200	—	1,300	900		
2. Naphthol	1,700	—	2,500	—		
3. Dinitro chloro-benzene.	1,500	—	1,000	500		
4. Dinitrotoluene ...	600	2,000	50	450		
5. Metanilic acid ..	900	—	690	210		
6. Dimethyl aniline	600	—	250	350		
V. Pesticidal Chemicals						
1. B.H.C.*	15,000	25,000	6,600	8,400		
2. D.D.T.*	6,000	9,000	2,800	3,200		
3. Aldrin and other chlorinated pesticides.	900	1,500	675	200		
4. Malathion	500	1,000	510	—		
5. Parathion	500	1,000	450(?)	—		
6. Copper oxychloride	2,000	—	2,300	—		
7. Dithio carbamates	200	—	2,000	—		
8. Organomercurials*	100	—	100	—		
9. Calc. Cyanide ..	200	—	—	200		
10. Ethylene dibromide*	500	—	110	390	250 tons for use in TEL fluid	
11. 2,4.D. and related Weedicide salts.	1,500	—	900	600		
12. Zinc Phosphide* ..	750	—	450	300		
VI. Synthetic Elastomers (not finally assessed so far and only tentative data)						
1. S. B. Rubber ..	30,000	30,000	30,000	—	Possible inter-changeability.	
2. Polybutadiene ..	30,000	80,000	20,000(?)	—		
3. Polyisoprene ..	—	30,000	nil	—		
4. Butyl rubber ..	10,000	30,000	nil	—		
5. Others (excl Polyurethanes.	2,000	10,000	nil	—		
VII. Plastics and Synthetic Resins						
1. Phenol formaldehyde moulding powder.*	6,000	12,000	5,000	(2 shifts)		
2. Phenolic resins, (including laminations and adhesives)	2,000	6,000	3,000			
3. U.F. moulding powder*	3,000	6,000	1,360	1,500		
4. U.F. Adhesive resins*	8,000	20,000	8,500	—		
5. Melamine resins ..	2,000	6,000	250	1,750	Linked to indigenous melamine capacity.	
6. Polyester resins ..	2,000	5,000	800	1,200	Linked to indigenous raw material production.	
7. Other types of resins like epoxy etc.	—	2,000	nil	—		

(1)	(2)	(3)	(4)	(5)	(6)
8. Low Density Polyethylene*	28,000	100,000	17,500	10,500	
9. High Density Polyethylene.	8,000	15,000	4,000	4,000	
10. Polypropylene ..	4,000	20,000	Nil	4,000	
11. Poly Vinyl chloride	30,000	75,000	35,000	—	
12. Polystyrene* ..	20,000	50,000	14,000	6,000	With styrene monomer
13. Cellulosics	7,000	10,000	6,500	—	Butyrate to be developed
14. Acrylics (methacrylate)	4,000	8,000	—	4,000	With Monomer.
15. Nylon	2,000	8,000	—	—	Linked to caprolactam.
16. Polyurethane ..	3,000	15,000	—	3,000	Linked to basic raw material production.
17. Polyvinyl acetate ..	2,000	8,000	4,800	—	With monomer.
18. Others	2,000	31,000	—	—	

VIII. Various fine Organic Chemicals required in quantities varying from about 500 to 1,500 tons, production of which would be inter-linked to establishment of capacity of major organic chemicals and various end-products such as plastics, rubber etc.

Acetoacetic ester, Organic Phosphates, Alkyl Phenols, Bi-Phenol, Sorbitol, Benzoic acid, Butylamines and other amines, Maleic acid, Acetophenone, Phenylacetic and amide, Picolines, MIBK, Ethanolamines, Peracetic acid, Methyl ethyl ketone, tetra ethyl lead etc.

Also other fine Organic Chemicals, Aromatic Chemicals and specialities whose requirements may be of the order of 100 to 300 tons per year.



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